# NATURAL GAS FOR AUTOMOTIVE USE IN CANADA: A STUDY OF MARKET PENETRATION PROBLEMS

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# NATURAL GAS FOR VEHICLES IN CANADA: A STUDY OF MARKET PENETRATION PROBLEMS

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CONTENTS

EXHIBITS ..... vii

FIGURES ..... vii

TABLES ..... vii

PREFACE ..... viii

EXECUTIVE SUMMARY ..... ix

CHAPTER 1 INTRODUCTION ..... 1

1.1 Introduction ..... 1
1.2 Objectives and Methodology ..... 2
1.3 NGV Conversion Considerations ..... 2

1.3.1 Benefits ..... 3
1.3.2 Costs ..... 4
1.3.3 Other Issues ..... 6

CHAPTER 2 CURRENT NGV MARKET STATUS ..... 11

2.1 Introduction ..... 11
2.2 NGV Market Status in Italy ..... 11
2.3 NGV Market Status in New Zealand ..... 13
2.4 NGV Market Status in the U.S. ..... 17
2.5 NGV Market Status in Canada ..... 17

2.5.1 Numbers of Vehicles Converted ..... 17
2.5.2 NGV Refueling Stations ..... 19

2.6 Emerging Technological Innovations ..... 24

2.6.1 On-Board Fuel Metering Developments ..... 24
2.6.2 On-Board Fuel Storage System ..... 28
2.6.3 Stationary Compression Systems ..... 31

2.7 Detailed Review of NGV Incentives and Relevant Policies ..... 32

2.7.1 Incentives in Canada ..... 32

2.7.1.1 Federal Government Grants ..... 32
2.7.1.2 Provincial Government Grants ..... 33
2.7.1.3 Utility Grants ..... 33

2.7.2 Incentives in Italy ..... 35

2.7.3 Incentives in New Zealand ..... 35

2.7.3.1 National Government ..... 35
2.7.3.2 Gas Utilities ..... 37

2.7.4 Incentives in the U.S. ..... 37

2.8 Summary ..... 40

CHAPTER 3 REVIEW OF MARKET PENETRATION FORECASTS ..... 43

3.1 Energy, Mines and Resources Canada's Perspective ..... 43
3.2 Provincial Perceptions and Forecasts of NGV Penetration ..... 49
3.3 Private Perceptions ..... 50
3.4 Institutional Barriers to NGV Conversions ..... 51
3.5 Summary ..... 52

CHAPTER 4 ISSUES IN NGV MARKET DEVELOPMENT ..... 55

4.1 Intercountry Comparison ..... 55
4.2 Issues in Market Development ..... 58

4.2.1 Fuel Price Differential Uncertainty ..... 59
4.2.2 Conversion Costs ..... 60
4.2.3 Compression Costs ..... 61
4.2.4 Propane Competition ..... 62
4.2.5 Low-Key Marketing Effort ..... 63
4.2.6 Lack of Refueling Stations ..... 63
4.2.7 Institutional Barriers ..... 64
4.2.8 Lack of Government Vehicle Conversion Commitment ..... 64
4.2.9 Lack of Technological Developments ..... 65

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS ..... 67

5.1 Fuel Price Differential Uncertainty ..... 67
5.2 Conversion and Compression Costs ..... 68
5.3 Propane Competition ..... 68
5.4 Low-Key Marketing Effort ..... 68
5.5 Lack of Government Vehicle Conversion Commitment ..... 69
5.6 Lack of Refueling Stations ..... 69
5.7 Institutional Barriers ..... 69
5.8 Lack of Technological Developments ..... 69

APPENDIX A STANDARDS AND FINANCIAL ANALYSIS OF VEHICLE CONVERSIONS ..... 71

BIBLIOGRAPHY ..... 97

## EXHIBITS


2.1 U.S. Barriers to NGV Use: Summary of Findings ..... 38

A.1 Canadian General Standards Board, Standard for Natural Gas Vehicles ..... 76

A.2 Vehicle Equipment Standards, Standard for Natural Gas Vehicles ..... 78

A.3 Economic Analysis Format ..... 79


## FIGURES


2.1 CNG (NGV) Refueling Stations in Italy ..... 12

2.2 Italian Fuel Prices ..... 14

2.3 Italian Fuel Price Differentials and Sales ..... 15

2.4 New Zealand NGV Refueling Station Map North Island ..... 16

2.5 Canadian Natural Gas Transmission and Distribution ..... 21


## TABLES


1.1 Vehicles Converted under Federal Assistance Programs ..... 7

2.1 Gas Utility NGV Vehicles in Canada ..... 20

2.2 Public NGV Fueling Stations and Their Fuel Prices ..... 22

2.3 Canadian Retail Gasoline Outlets by Province May 1, 1983 ..... 23

2.4 Future NGV Service Stations ..... 25

2.5 Comparisons of On-Board Equal Capacity Storage Systems ..... 30

2.6 Provincial Government and Utility NGV Incentives ..... 34

3.1 Canadian "Motor Truck" Fleets by Size and Province ..... 47

3.2 NGV Target Markets in the Private Sector ..... 48

## PREFACE

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## EXECUTIVE SUMMARY

In Italy the use of natural gas as a vehicle fuel has been very popular since the 1930s. In the last 10 years interest in the same fuel has risen in New Zealand, the United States, Canada and other countries. Natural gas for vehicles (NGV) has penetrated the transportation fuel market in Canada only to a very limited extent with about 3,000 vehicles now relying on it. Given the abundance of natural gas in Canada and the attractive economics of switching to NGV in the case of commercial vehicles such as delivery vans and taxicabs, this low penetration is surprising.

This report compares NGV markets in Italy, New Zealand, the United States and Canada with the emphasis on identifying reasons why natural gas is an attractive fuel for vehicles in Italy and New Zealand while apparently much less so in the U.S. and Canada. Identifying the reasons for low NGV penetration in Canada suggests means by which NGV can be made more competitive with conventional sources of transportation energy. The research has indicated that serious obstacles have so far prevented NGV from becoming the fuel of choice for many potential vehicle convertors. These include:

- fuel price differential uncertainty,
- high vehicle conversion costs,
- high compression equipment costs,
- tough competition from propane,
- a demonstrated lack of government vehicle conversion commitment,
- a low-key marketing effort,
- certain institutional barriers to NGV use, and
- lack of technological developments.

These obstacles conspire in many cases to prevent potential vehicle convertors from switching to an NGV capability. The author recommends that:

- governments make a commitment to long-term stable taxation of transportation fuels,
- innovative financing arrangements such as cylinder leasing and low interest loans be made to lower initial conversion costs,
- research should continue to improve NGV as an alternative fuel,
- a greater government vehicle conversion commitment to NGV use be made to establish greater public confidence,
- more effort be devoted to advertising NGV, and
- institutional barriers to use of NGV be identified and removed by a concerted effort of all levels of government and the NGV industry.

# Chapter 1

## INTRODUCTION

### 1.1 Introduction

Natural gas has been used as a vehicle fuel in countries other than Canada, notably Italy and New Zealand, for many years. Only recently has it been used in the transportation sector in Canada and only on a small scale. This is not surprising given the absence of gasoline supply problems and relatively low prices. However, the spectre of declining conventional oil reserves and higher oil prices has generated an increased interest in using natural gas in the internal combustion engine in Canada. Currently, natural gas for vehicles (NGV) offers a significant degree of economy of operation relative to gasoline use. This is singularly the most important factor in the utilisation of natural gas vis-a-vis gasoline. The use of natural gas offers savings of from 40 to 50 percent on fuel bills compared to gasoline. As an example, a taxi converted to run on NGV in Calgary, where the price spread between gasoline and natural gas is about $0.18 per litre, would save about $2,900 per year based on 80,000 kilometres per year (km/yr) of driving. This represents a payback period on the conversion investment of less than one year. NGV vehicles which are used less intensively (say, 20,000 km/year) can still save their owners over $700 per year. A more detailed example is provided in Appendix A.

In the Montreal area, where gasoline is usually more expensive than in Western Canada, the price spread between regular leaded gasoline (54 cents per litre as of summer 1984) and NGV (34 cents per litre equivalent) is even more pronounced at 20 cents per litre. In Vancouver, the fuel price differential is one of the highest in the country at 30 cents per litre. In addition a system of federal and provincial government grants and utility grants in some areas now offer reduced conversion costs to consumers to utilise natural gas in place of gasoline. These incentives are detailed in Chapter 2 along with other government policies designed to increase the attractiveness of NGV, also referred to as compressed natural gas (CNG).

In spite of the generally attractive economic rationale of NGV use, strongly reinforced by the incentives mentioned above, vehicle conversions to natural gas have been limited, especially relative to the number of conversions to propane. Propane is a strong competitor to NGV. In the Calgary area propane sells for about 73 percent of the litre-equivalent cost of regular leaded gasoline while NGV sells for about 64 percent of the litre-equivalent cost. These relative price relationships are generally the same across Canada.

### 1.2 Objectives and Methodology

The objective of this report is to determine whether there are serious barriers in the way of greater utilisation of NGV in Canada, or alternatively, if there are incentives which would, at moderate cost, make NGV a stronger competitor in the alternative vehicular fuels market.

Because some countries, notably Italy, New Zealand and the United States, have had more experience with NGV than Canada, examining the NGV markets in those countries may help the understanding of the Canadian market.

These questions are pursued in Chapter 2 by surveying the current NGV situation in Canada, California, New Zealand and Italy. Chapter 2 also provides details on the current government and natural gas industry policies and incentives pertaining to expanded use of NGV. The question of emerging technological advances which should increase the attractiveness of NGV to motorists in the future is also examined.

Chapter 3 provides a review of Canadian NGV market penetration forecasts and issues. With these insights into the current situation, further policy initiatives are suggested in Chapter 4 which might help to increase the rate of adoption of NGV in Canada's transportation sector. Chapter 5 provides a brief summary and conclusions.

### 1.3 NGV Conversion Considerations

As mentioned above, the utilisation of natural gas can produce important savings for vehicle operators but as with any other endeavour, there are private and social benefits, costs and externalities associated with converting vehicles to NGV use. From the private perspective, economy is the main incentive for converting, but relatively high conversion costs must be incurred in the process. From

the broader social perspective, more than economy is important due to the strong externalities associated with the private use of NGV (i.e., environmental protection and balance of payment effects). The following is a brief review of the benefits and costs of NGV use. These issues are discussed at greater length in the references listed.

### 1.3.1 Benefits

In areas where NGV is available, per unit natural gas costs are usually considerably lower than gasoline costs on a litre-equivalent basis. For example, at the time of writing (Fall 1984), natural gas delivered to a vehicle storage tank in Calgary is about 27 cents per litre equivalent, whereas regular leaded gasoline on average sells at the retail level for about 42 cents per litre.[1] If a large amount of fuel is used annually, the differential will clearly generate large savings.

A second significant economic benefit to the user of NGV stems from its clean burning characteristics and related absence of cylinder gasoline-wash problems and lubricant contamination. Engines fueled with natural gas rather than gasoline may have extended service intervals producing savings in lubricating oil and service parts, although this has not been proven in all cases.

Hot weather vapour lock problems are also eliminated when NGV is used.

In engines dedicated to NGV (no dual fuel option), the static compression ratio can be raised from an average of 8:1 to 12:1 to increase the engine's thermal efficiency. This is possible because NGV's natural research octane number is 130, compared with that of typical regular leaded gasoline of approximately 94.[2] Fully optimized dedicated NGV engines (converted gasoline engines) would likely be about 8 to 10 percent more efficient. Currently, there are about 3,000 Canadian NGV vehicles but only a very small number (about 5 vehicles) are truly dedicated to NGV. The majority can still be switched back to gasoline at the turn of a switch.

The use of NGV also enhances the vehicle operational safety for dedicated vehicles. Because of the tremendous strength of NGV cylinders, the likelihood of a catastrophic rupture resulting from an accident is virtually nil. If a fuel system leak develops, the natural gas will dissipate quickly in ambient conditions. In contrast, gasoline

line tank rupture can often produce disastrous results. In countries where NGV has been used for years, the fuel has an excellent safety record.[3]

A social benefit associated with natural gas as a transportation fuel is the concomitant reduction in harmful exhaust emissions. Unburned hydrocarbons (non-methane), oxides of nitrogen and carbon monoxide are reduced relative to other vehicles. Furthermore, no polluting anti-knock additive is required with NGV.[4]

Although hydrocarbon emissions in the form of methane will be greater with natural gas fueling, methane is less reactive in the atmosphere and thus is not a large contributor to photochemical smog. Generally, non-methane hydrocarbon emissions are cut in half. Oxides of nitrogen emissions may be somewhat reduced. During engine warm up periods when gasoline is less than fully vapourised, NGV produces significantly less pollution than does a gasoline fueled engine.

Another social benefit resulting from widespread use of NGV in Canada would be a reduction in oil imports. Since all NGV would be supplied from Western Canada, fewer imports of oil into the Eastern Canadian market would be required. This would have important balance-of-trade effects.

### 1.3.2 Costs

Costs would be incurred in producing the above benefits from increased NGV use. These are both real expenses and "inconvenience-type" costs.

Conversion costs must be incurred in most cases because few factory-built NGV vehicles are available. This is a one-time only cost of about $1,800 to $2,800 depending on the vehicle.[5] Government and, in some areas, natural gas utility company grants are available to partially offset this cost. In some provinces sales tax rebates are also available.

The incremental new vehicle cost of the natural gas option might be in the range of $500 to $1,000.

For vehicles where payload capacity is important, the volume and weight of the NGV tanks will impose a cost by reducing that

payload and travel range. For commercial vehicles, such as taxis or delivery vans, this may impose a real monetary cost. For private vehicles this may be perceived as an inconvenience. The driving range on one standard fuel fill with NGV is much less than that on gasoline. However, the addition of the NGV system to a gasoline fueled vehicle will extend the range considerably. Two standard NGV cylinders holding about 20 cubic metres of compressed natural gas are equivalent to only 36 litres of gasoline, about half the capacity of an intermediate size North American car.

It should be noted that in some cases conversion of vehicles to NGV may result in cold starting problems at very low ambient temperatures. Although service intervals may be extended in some cases, some studies show that this is not justified. Valve seat recession may also be a problem in high output natural gas fueled engines. However, this can be remedied by the use of hardened seat inserts at additional cost.[6] Light and medium duty engines in cars and light trucks are relatively free of this problem.

Because the NGV distribution network is very limited in Canada, vehicles which do not return to a central base, as fleet operators do, may experience inconvenience in refueling.

In most cases, fleet operators' refueling facilities are not open to the general public. The owner of a private NGV-powered vehicle must then search out a public station of which there are few across Canada. As of early 1985 there were 28 public stations operating with another 55 station grants approved. Thus, the inconvenience in NGV refueling will be experienced not just in travelling across Canada but even within major cities.

For operators of refueling facilities, the addition of an NGV delivery system will cost about $225,000--mainly for the compression system.[7] The total cost will vary with the capacity of the system. A federal grant of $50,000 is available to operators to reduce this cost.

This brief review of NGV benefits and costs illustrates the complexity of the issue for vehicle owners. Although the fuel is clearly cheaper than gasoline, there are other issues to consider before converting to NGV. From the private perspective there is a tradeoff to make. This is based on pure monetary calculation. Considering the differential in fuel pr[illegible] and the costs involved in

converting, is it economically attractive? In most locations in Canada this calculation will show that converting is economically very attractive. In the example cited in Section 1.1 the Calgary taxi was able to save $2,900 per year by converting to NGV. If the complete vehicle conversion cost is $2,500 (less a $500 federal government grant), then the decision to convert the vehicle pays back in less than a year of operation.[8]

### 1.3.3 Other Issues

There are other aspects to consider. For example, will the monetary savings compensate for the shortage in driving range and the paucity of NGV filling stations? In some situations it will, but not in others. If the taxi in the above example is not required to travel routes that would be compromised by the reduced range, and it can refill at a central base once a day, then any inconvenience is likely to be insignificant beside the annual monetary savings.

Issues such as public concern for safety can largely be eliminated by an educational program designed to dispel fears about high pressure natural gas. Another issue, however, is the question of competing alternative fuels--the most important being propane. Vehicle conversions to propane have far outstripped conversions to NGV. There are already about 120,000 propane powered vehicles in Canada, and federal grant programs show consistently higher rates of conversion to that fuel vis-a-vis NGV as indicated in Table 1.1.

There are good reasons for this, chief among them being:

- propane is also much less expensive than gasoline,
- conversion costs are considerably lower for propane,
- auto-propane distribution is already well established with at least 1,400 retail outlets selling propane in Ontario alone and about 5,000 in Canada, and
- the energy density of propane is closer to (although not equal to) that of gasoline, providing a greater range capability per refueling.

The fact that propane offers strong competition in the alternative vehicle fuels market is likely a major impediment to widespread adoption of NGV. This will be discussed in more detail in Section 4.2.4.

TABLE 1.1

VEHICLES CONVERTED UNDER FEDERAL ASSISTANCE PROGRAMS[a]

| | to Natural Gas | | | to Propane | |
|---|---|---|---|---|---|
| | Natural Gas Vehicle Program | % of Cdn. Total | CNG Demo | Number | % of Cdn. Total |
| Atlantic Canada | 0 | 0 | 0 | 171 | - |
| Quebec | 509 | 32 | 94 | 1,929 | 4 |
| Ontario | 301 | 19 | 81 | 27,117 | 54 |
| Manitoba | 0 | 0 | 0 | 1,436 | 3 |
| Saskatchewan | 0 | 0 | 10 | 1,206 | 2 |
| Alberta | 289 | 18 | 51 | 10,903 | 22 |
| British Columbia | 506 | 32 | 254 | 7,145 | 14 |
| Total | 1,605[b] | 100 | 490 | 49,907 | 99 |

SOURCE: Energy, Mines and Resources Canada, "Propane Vehicle Grant Program" (Ottawa: Energy, Mines and Resources Canada), 1983.

[a]Conversions performed to the end of December 1984. CNG Demo was the federal program which preceded the Natural Gas Vehicle Program. It was terminated in March 1983. Total conversions under both the Demo and Natural Gas Vehicle Programs are 2,095.

[b]The actual number of conversions is about 3,000. Many have been converted without the assistance of the federal grant.

An important social and private issue relevant to any alternative fuels discussion is the question of optimal depletion of current assets such as crude oil refineries and gasoline distribution systems. Canada has a sizable investment in refineries, a distribution system and service stations which are oriented towards selling gasoline and diesel fuel. Widespread movement to alternatives such as NGV means reduced capacity utilisation for refineries and under-utilisation of distribution system components such as tanker trucks, storage depots and dispensing pumps. This would imply a reduced return on the past investment in these facilities which, in some cases, have not yet been fully amortized. As well, addition of NGV compression systems to service stations will be required. This complicates the important question of how fast the move to alternative fuels should be. While supplies of crude oil are adequate, the liquid fuels system should be depleted at an optimal rate, allowing depreciation of past investments in crude oil based fuels facilities.

**Footnotes**

[1]Survey of local stations by author. NGV is generally sold by the kilogram (a unit of mass) but to compare prices with gasoline it can be measured in price per litre equivalent--that is, the amount which provides combustion energy equivalent to a litre of regular leaded gasoline.

[2]Energy, Mines and Resources Canada, "Alternative Fuels, Production Costs," Report TE-82-7, report prepared by PPS Ltd. and R. T. Webb Corporation (Ottawa: Energy, Mines and Resources Canada, February 1983).

[3]Dr. J. Winston Porter, "Environmental and Safety Aspects of Natural Gas-Fueled Vehicles," Nonpetroleum Vehicular Fuels II (Chicago, Illinois: Institute of Gas Technology, June 1981), p. 42.

[4]Ibid., p. 45. In fact the atmospheric emissions of the "total" natural gas system from production to consumption are considerably lower than with any other fuel system.

[5]Communication with CNG Fuel Systems Ltd., May 1984.

[6]Energy, Mines and Resources Canada, "Natural Gas, Canada's Transportation Fuel," TE-84-03, report prepared by John S. Heenan (Ottawa: Energy, Mines and Resources Canada, 1984). Also personal communications with the B.C. Research Council.

[7]Communication with CNG Fuel Systems Ltd., May 1984.

[8]Energy, Mines and Resources Canada, Natural Gas: An Alternative Transportation Fuel, Cat. No. M27-54/1983 (Ottawa: Minister of Supply and Services Canada, 1983), p. 7. A better way of estimating relative economic attractiveness is to use a net present value estimation procedure which evaluates all relevant costs and benefits.

# Chapter 2

## CURRENT NGV MARKET STATUS

### 2.1 Introduction

The penetration of NGV in the transportation market varies in the few countries where it is used. The oldest user of NGV, Italy, has a much greater level of penetration than other countries. New Zealand and the United States, although relatively newer users of NGV, have experienced rapid increases in the number of vehicles fueled by natural gas. The purpose of this chapter is to compare and contrast those countries which have experience with NGV, with the developing Canadian situation. Four countries will be reviewed: Italy, New Zealand, United States and Canada.

### 2.2 NGV Market Status in Italy

The Italians have had a great deal of experience with using natural gas in vehicles. The first vehicles were converted to dual fuel use in the early 1920s and the number of vehicles has continually grown. Current estimates suggest that over 300,000 vehicles (about 90 percent of these are commuter vehicles) run on NGV dual-fuel systems in Italy.[1] As a percentage of the overall automotive fleet this is a small number, about 2 percent. In Italy about 730,000 public transport and private vehicles are fueled with propane. In 1984 about 350 million cubic metres of NGV were sold, 40 percent of this coming from domestic sources.

This population of vehicles is serviced by a network of 225 individual stations dispensing NGV in Central and Northern Italy. The general refueling network is shown in Figure 2.1. Not all of these stations are connected to the natural gas distribution grid. Only 135 are connected to pipelines. The rest are simple transfer (daughter) stations which are supplied with NGV from cylinder delivery trucks. Of these stations only about 33 are owned by the Italian SNAM Corporation, while the rest are operated by smaller private service companies that might own two or three. This provides a ratio of 1,227 vehicles per NGV service station as of December 1984. Currently, there are plans to

SOURCE: Pietro Magistris and Gustavo Bonvecchiato, "Compressed Natural Gas Distribution System in Italy." Published in Nonpetroleum Vehicular Fuels II, by Institute of Gas Technology, November 1981.

**FIGURE 2.1: CNG (NGV) REFUELING STATIONS IN ITALY**

extend the NGV station network into Southern Italy with the addition of about 220 new filling stations.

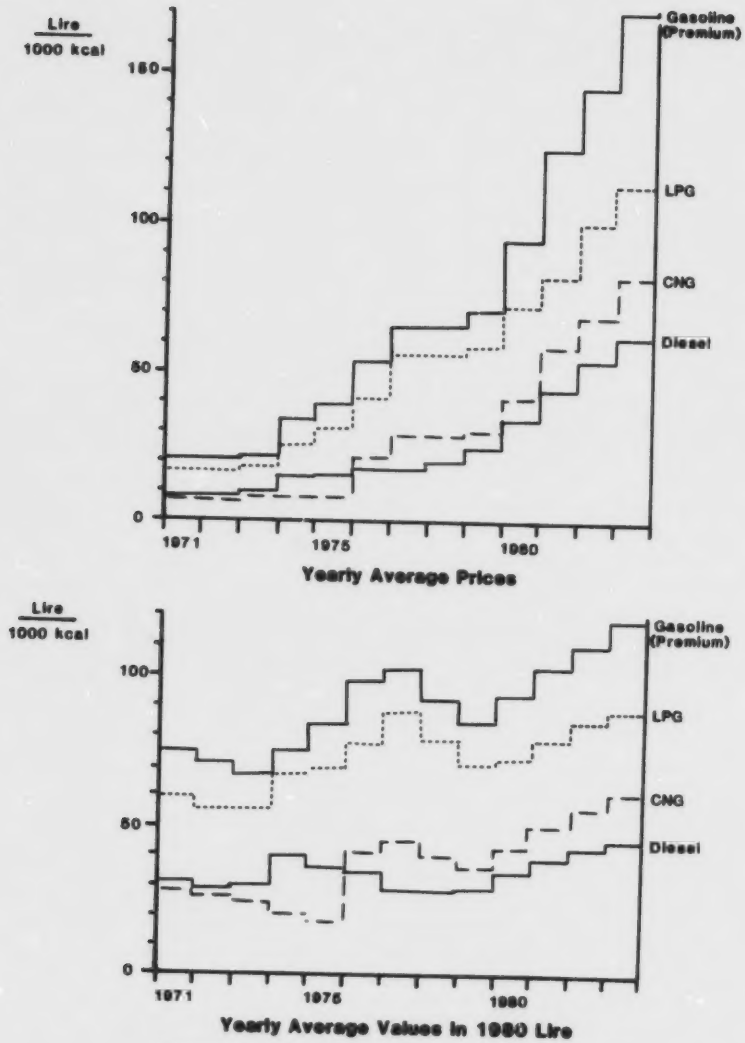
The major incentive to switch to an alternative transportation fuel is reduced operating costs. In Italy NGV service has been significantly less expensive than gasoline. Figure 2.2 shows average prices in current and constant dollars. Figure 2.3 shows the differential between NGV and gasoline prices. Although this differential has varied in Italy, it was higher in 1981 in absolute terms than it was in 1959. In 1981 NGV was only 46 percent of the price of gasoline. In 1959 it was 36 percent of the price of gasoline. In the 1980s this differential has been widening. For comparison purposes the Italian NGV price in 1980 in Canadian dollars was 44.5 cents per litre.

This very favourable relative price differential, reinforced by the excellent availability of NGV in Italy, explains the large number of NGV vehicles in use there. As of January 1, 1985 the Italian Government has altered the fuel taxation structure on conventional and alternative fuels. Taxes on gasoline and diesel fuel were increased by 2 and 8 percent, respectively, while taxes on both propane and NGV were reduced to 48 and 35 percent, respectively, of their previous levels. In absolute terms the tax on NGV is now only 13 percent of that on gasoline. Currently, taxes are 66 percent of the retail price of gasoline, 32 percent of the price of diesel, 40 percent and 21 percent of the selling prices, respectively, of propane and NGV in Italy.

### 2.3 NGV Market Status in New Zealand

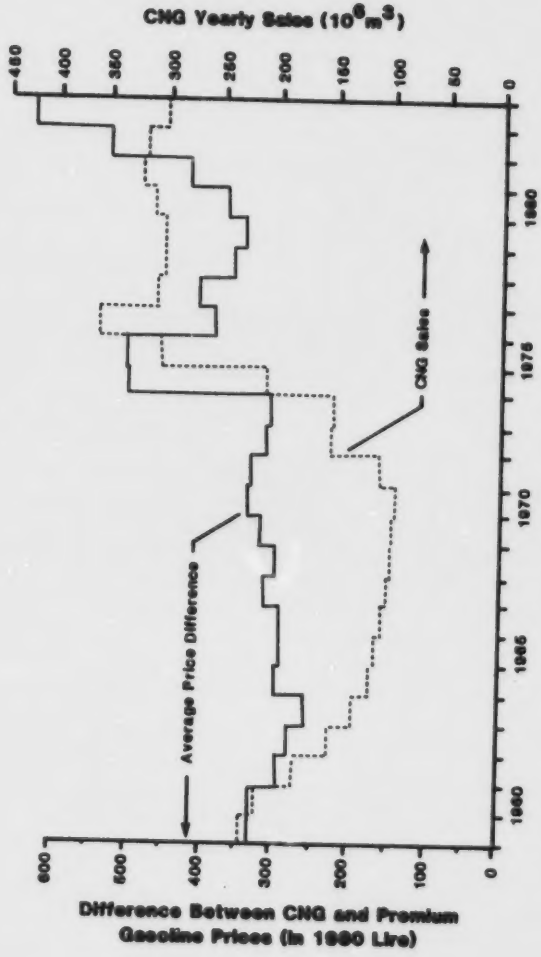
New Zealand has a significant indigenous supply of natural gas from the Kapuni and Maui offshore fields and has had considerable experience with NGV. Estimates as of January 1985 place the number of NGV vehicles operating in New Zealand at about 90,000.[2] This is the second largest NGV population in the world next to that of Italy. In New Zealand there have been many private vehicles converted to NGV as well as many fleets. The government is committed to converting most fleet vehicles to NGV. Over 2,500 Post Office fleet vehicles operate on NGV.

As of January 1985, New Zealand had 220 public refueling stations and 67 fleet stations in 41 communities. This provides a ratio of 313 vehicles per station in New Zealand. Figure 2.4 shows the distribution of the refueling network in New Zealand's North Island. NGV is available only on the north island.




SOURCE: Magistris and Bonvecchiato, "Compressed Natural Gas Distribution System in Italy."

FIGURE 2.2: ITALIAN FUEL PRICES




SOURCE: Magistris and Benvecchiato, "Compressed Natural Gas Distribution System in Italy."

FIGURE 2.3: ITALIAN FUEL PRICE DIFFERENTIALS AND SALES

NOTE: NGV is available on the north island only

SOURCE: Government of New Zealand Pamphlet

**FIGURE 2.4: NEW ZEALAND NGV REFUELING STATION MAP NORTH ISLAND**

The average price of NGV in litres of gasoline equivalent in January 1985 was 41-45 cents. This compares favourably (about 48 percent) with gasoline at 90 cents.

## 2.4 NGV Market Status in the U.S.

American experience with NGV dates back to 1966 when the San Diego Gas and Electric Company converted some fleet vehicles to run on liquified natural gas. Plans to convert more vehicles were stalled due to the mid-1970s perceived natural gas shortage. The Southern California Gas Company converted about 1,000 vehicles of its own fleet to NGV in 1970. Pacific Lighting (Southern California Gas's parent company) established another subsidiary to supply conversion equipment to fleet operators in California and nationwide. By 1978 Pacific Lighting had converted about half of its own fleet to NGV (about 2,400 vehicles). Interest in converting to NGV by other operators was greatly reduced in the late 1970s by the natural gas supply problems. As the supply constraints have been eased since that time, interest in converting fleet vehicles has increased.

NGV is used in many natural gas serviced areas in the U.S. including Alaska. Estimates suggest that about 30,000 vehicles run on NGV in the U.S., less than 1 percent of the vehicle population.[3] These are overwhelmingly company fleet vehicles which refuel at company maintenance centres. Fleet sizes vary from around 6 to 2,400 vehicles. American emphasis has been on converting fleet vehicles with no effort directed at the individual passenger car owner. Currently there are no public refueling stations in the United States. There are 6 individual companies which supply turnkey fleet conversions in the U.S.

American Gas Association estimates suggest that on average NGV provides, on a gasoline-equivalent basis, 30 to 50 percent fueling savings over gasoline.

## 2.5 NGV Market Status in Canada

### 2.5.1 Numbers of Vehicles Converted

The current use of NGV in Canada is very limited. Industry estimates suggest that about 3,000 fleet and individually owned vehicles across Canada operate on natural gas (the vast majority of these being dual fuel vehicles). This represents about 0.019 percent

of the total Canadian automotive fleet. In the province of Quebec there are about 750 NGV vehicles, 500 in Ontario, 700 in Alberta and 1,000 in British Columbia. The vast majority of these vehicles are part of company fleets which usually operate from a central refueling depot. Furthermore, most are used only in urban areas such as Montreal, Toronto, Calgary or Vancouver. However, in Alberta and British Columbia, companies which have natural gas production facilities in rural areas are increasingly utilising high pressure natural gas from their own pipelines as a vehicle fuel.

Although conversion of any high annual mileage vehicle is generally an attractive investment, it becomes even more so when the available conversion grants are considered. Although many vehicles were converted before the federal grant was implemented, the federal Natural Gas For Vehicles Assistance Program, which has been in existence since February 1983, has aided in conversion of 1,605 vehicles (for the period February 5, 1983 to December 1984).[4] These vehicles were all eligible for a taxable $500 federal conversion grant. The CNG Demo Program (its predecessor) aided in conversion of 490 vehicles to NGV with a $600 per vehicle grant. Accordingly, about 1,500 vehicles may have been converted to NGV in Canada without the aid of the federal grant, although other grants may have been available.

The distribution of vehicle conversions under the federal programs is very uneven. British Columbia and Quebec have been the most important provinces for conversions to NGV, both with 32 percent. Ontario and Alberta follow at 19 and 18 percent, respectively.

To put these numbers in perspective the Canadian road transport fleet in 1982 was composed of about 13 million vehicles of which 10 million were automobiles or light trucks running on gasoline, 2.8 million were commercial vehicles fueled with gasoline and about 0.16 million were commercial diesel vehicles.[5] Natural gas and propane fueled vehicles (using numbers of vehicles converted under the federal programs) composed about 0.27 percent of that total. Using total conversion estimates the percentage is about 0.79.

The first company in Canada to use NGV was Canadian Western Natural Gas (CWNG) in Calgary which, in the late 1960s, fueled over 100 of its own fleet vehicles with NGV. Equipment problems forced them to abandon NGV for most of these vehicles. Now, with more reliable equipment, they are once again converting some of their fleet vehicles to NGV.

Like CWNG, other Canadian natural gas distribution utilities are converting fleet vehicles to NGV. Table 2.1 provides a listing of these committed utilities, the number of vehicles they have converted and their goals for the year end (1985). The natural gas distribution utilities have a strong incentive in providing leadership in NGV conversion because many utilities are facing declining loads in other markets (residential space heating, for example) due to conservation measures. Furthermore, greater utilisation of NGV would improve the distribution utilities summertime load factor.

Natural gas producers have also taken the opportunity to use their own product to fuel some of their rural fleet service vehicles. Nova Corporation, Petro-Canada, Amoco Petroleum, Alberta Energy Company and others utilize high pressure pipeline gas usually with supplementary compression to fuel vehicles.

### 2.5.2 NGV Refueling Stations

The lack of convenience associated with a quite limited NGV distribution network has undoubtedly affected the number of vehicle conversions. The current Canadian NGV distribution system is extremely limited, although the natural gas distribution network serves most of the country (see Figure 2.5). Across Canada, as of December 1984, there were 22 public refueling stations selling NGV. These are listed in Table 2.2 along with gasoline equivalent NGV prices.[6] This list is expected to expand considerably by the end of 1985.

The public NGV stations are supplemented by other compressor stations located in company maintenance yards which are usually devoted exclusively to fleet use and are not available for general public refueling. The public stations are generally conventional retail gasoline outlets which have added compression equipment to boost natural gas distribution pressure to 21 megapascals (MPa)--3,000 pounds per square inch (psi)--for cylinder charging. The service station must be served by natural gas, of course, before it can supply NGV.

The number of NGV refueling stations is minuscule in comparison with the 21,856 retail gasoline outlets in Canada as of May 1, 1983. Table 2.3 shows the provincial and corporate breakdown of retail gasoline outlets as of that date.[7] The four public NGV stations in Ontario are dwarfed by the more than 6,200 public gasoline stations. British Columbia and Quebec have the largest number of public NGV

TABLE 2.1

GAS UTILITY NGV VEHICLES IN CANADA

| Utilities | Converted Vehicles | |
|---|---|---|
| | Current (Dec. 1984) | Target by Year End 1985 |
| Gaz Metropolitain, Montreal | 200 | 250 |
| Consumers Gas, Mississauga | 150 | 550 |
| Union Gas, Chatham | 120 | 225 (800)[a] |
| Greater Winnipeg Gas, Winnipeg | Study in Progress | |
| Saskatchewan Power Corporation, Regina | 16 | 16 |
| Canadian Western Natural Gas, Calgary | 39 | 60[b] |
| Northwestern Utilities, Edmonton | - | 10 |
| B.C. Hydro, Vancouver | 50 | 70+ |

SOURCE: Personal communication with utilities.

[a]End of fiscal year 1986.
[b]CWNG intends to convert about 30 vehicles per year for the next 5 years.

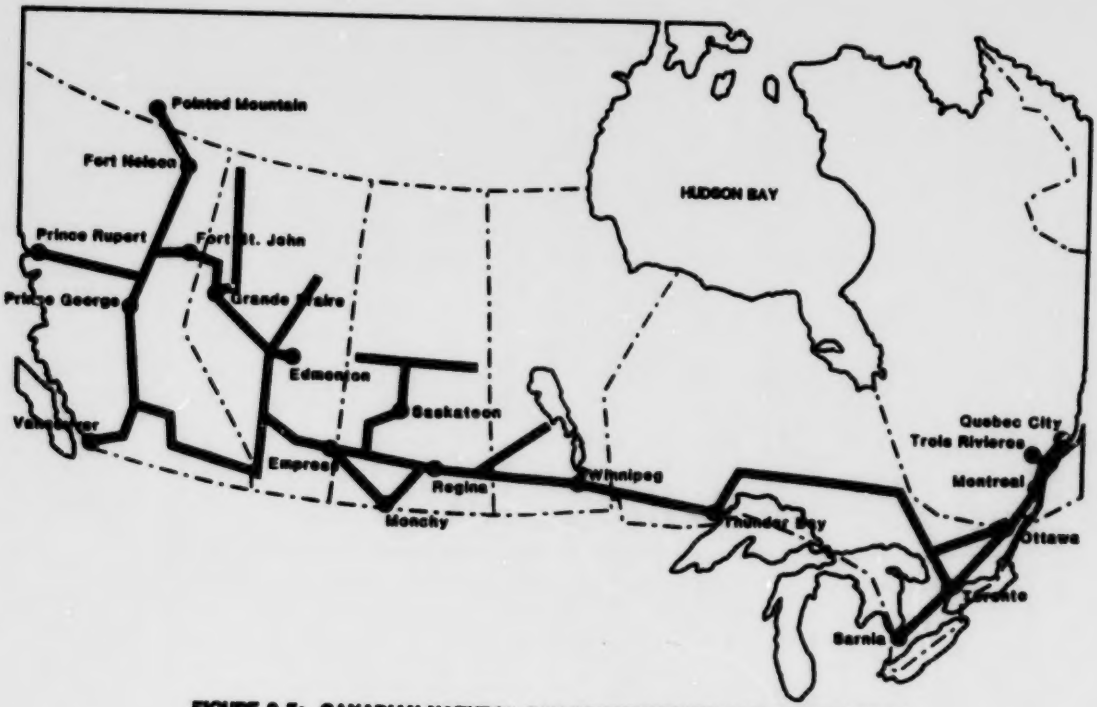



FIGURE 2.5: CANADIAN NATURAL GAS TRANSMISSION AND DISTRIBUTION

TABLE 2.2

PUBLIC NGV FUELING STATIONS AND THEIR FUEL PRICES

**Alberta**

Husky Oil
2525 - 32nd Avenue N.E.
Calgary, Alberta
(Natural Gas - 26.5¢/litre)

Palliser Square Husky Service
120 - 10th Avenue S.W.
Calgary, Alberta
(Natural Gas - 26.5¢/litre)

**British Columbia**

Husky Oil Service Station
750 West 70th Ave.
Vancouver, B.C.
(Natural Gas - 26.6¢ litre)

Black Top and Blue Cabs Service Station
711 Beach Avenue
Vancouver, B.C.
(Natural Gas - 34¢/litre discount available to the public)

Doug Logan's Island Service (Petro-Canada)
11991 Stevenson Highway
Richmond, B.C.
(Natural Gas - 26.3¢/litre)

Mohawk Oil Company Ltd.
884 Columbia Street West
Kamloops, B.C.
(Natural Gas - 27.5¢/litre)

Prince George Taxi
331 First Ave.
Prince George, B.C.
(Natural Gas - 27.5¢/litre)

National Energy Equipment
7353 - 6th Street
Burnaby, B.C.
(Natural Gas - 25.9¢/litre)

Tundra Turbos
7907 - 101 Ave.
Fort St. John, B.C.
(Natural Gas - 23¢/litre)

Husky Oil
21592 Lougheed Highway
Hapleridge, B.C.
(Natural Gas - 23.8¢/litre)

**Ontario**

Shell Service Station
1285 The Queensway
Toronto, Ontario
(Natural Gas - 23.8¢/litre)

Shell Canada and Union Gas
Chatham, Ontario
(Price N.A.)

Save-U Station
London, Ontario
(Price N.A.)

Shell Canada and Union Gas
Hamilton, Ontario
(Price N.A.)

**Quebec**

Centre Shell Saint-Leonard
5200, Boulevard Metropolitain
Montreal, P.Q.
(Natural Gas - 34¢/litre)

Station Gulf
11,000, Cote de Liesse
Lachine, P.Q.
(Natural Gas - 34¢/litre)

Station Shell
9600, Henri Bourassa ouest
Saint-Laurent, P.Q.
(Natural Gas - 34¢/litre)

Station Ultramar
2001, Chemin Chambly
Longueuil, P.Q.
(Natural Gas - 34¢/litre)

Station Shell
6505, boul. Henri Bourassa est
Ville de Montreal-Nord, P.Q.
(Natural Gas - 34¢/litre)

Station Ultramar
5600, boul. Jean XXIII
(coin Cote Richelieu)
Ville de Trois-Rivieres ouest P.Q.
(Natural Gas - 34¢/litre)

Station Gulf
2940, boul. Laurier
Ville de Sainte-Foy, P.Q.
(Natural Gas - 34¢/litre)

**Saskatchewan**

CNG Autoenergy
1850 First Avenue
P.O. Box 1365
Regina, Saskatchewan
(Natural Gas - 25¢/litre)

SOURCE: Energy, Mines and Resources Canada, "Natural Gas, Canada's Transportation Fuel," Report TE-84-03, report prepared by John S. Keenan (Ottawa: Energy, Mines and Resources Canada, 1984).

NOTE: N.A. = not available.

TABLE 2.3

CANADIAN RETAIL GASOLINE OUTLETS BY PROVINCE
MAY 1, 1983

| | B.C. | Alta. | Sask. | Man. | Ont. | Que. | N.B. | N.S. | P.E.I. | Nfld. | NWT & Yukon | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Les Petroles Calex | - | - | - | - | - | 85 | - | - | - | - | - | 85 |
| Canadian Tire | - | 3 | - | - | 6 | 10 | - | - | - | - | - | 89 |
| Chevron Canada | 313 | - | - | - | - | - | - | - | - | - | - | 313 |
| Federated Co-ops | 43 | 69 | 341 | 143 | - | - | - | - | - | - | - | 596 |
| Mr. Gas Ltd. | — | - | - | - | 22 | 8 | - | - | - | - | - | 30 |
| Gulf Canada | 275 | 391 | 344 | 233 | 527 | 517 | 42 | 71 | 10 | 60 | 26 | 2,496 |
| Husky Oil | 81 | 97 | 26 | 36 | 50 | - | - | - | - | - | 4 | 294 |
| I.C.G. Liquid Gas | 15 | 13 | 8 | 3 | 3 | - | - | - | - | - | - | 42 |
| Imperial Oil | 458[a] | 382[b] | 350 | 270 | 974 | 712 | 232 | 186 | 46 | 187 | - | 3,797 |
| Irving Oil[c] | - | - | - | - | - | 799 | 663 | 304 | 33 | 148 | - | 1,947 |
| Mohawk Oil | 90 | 119 | 28 | 27 | 3 | - | - | - | - | - | - | 267 |
| Natomas of Canada[d] | - | - | - | - | 48 | 103 | - | - | - | - | - | 151 |
| Petro-Canada | 195 | 117 | 44 | 33 | 1,301 | 1,033 | 95 | 139 | 13 | - | 6 | 2,976 |
| Pioneer Petroleums | - | - | - | - | 70 | - | - | - | - | - | - | 70 |
| Shell Canada[e] | 339 | 288 | 214 | 304 | 1,201 | 836 | 130 | 118 | 30 | - | 5 | 3,465 |
| Spur Oil | - | - | - | - | 10 | 138 | - | - | - | - | - | 148 |
| Suncor | - | 2 | - | - | 544 | 328 | - | - | - | - | - | 874 |
| Tempo Petroleum | 17 | 14 | 111 | 88 | 3 | - | - | - | - | - | - | 233 |
| Texaco Canada | 195 | 214 | 137 | 117 | 982 | 777 | 145 | 135 | 27 | 40 | - | 2,769 |
| Top Value Gasmarts | - | - | - | - | 119 | 26 | - | - | - | - | - | 145 |
| Turbo Resources | 29 | 104 | 48 | 11 | 67 | - | - | - | - | - | 2 | 261 |
| Ultramar Canada | - | - | - | - | 237 | 393 | 1 | - | - | 177 | - | 808 |
| Totals | 2,050 | 1,813 | 1,651 | 1,265 | 6,237 | 5,765 | 1,308 | 953 | 159 | 612 | 43 | 21,856 |

SOURCE: Oilweek, June 27, 1983.

[a]Includes Yukon
[b]Includes Northwest Territories
[c]Estimate
[d]Includes D-X Oil in Ontario and Independent Gas Stations in Quebec
[e]Includes Beaver Services Centres

refueling stations. Natural gas pipeline service has now been extended as far east as Quebec City so that NGV refueling services could be built from Vancouver to Quebec City.

Table 2.4 shows the locations of NGV stations to be opened in the near future.

## 2.6 Emerging Technological Innovations

The Italians refined the original NGV fuel system to the point where it has worked well within their climatic and market requirements. However, despite some claims to the contrary, adapting the Italian technology to Canadian markets with winter weather much colder than that experienced in Italy has not proven particularly easy. Several problem areas have been identified with such systems that tend to interfere with the potential of the basic fuel form itself. These areas are:

- on-board fuel metering and mixing system,
- on-board fuel storage system, and
- stationary compression systems.

Other important issues are system reliability, fuel leaks, idling and cold starting problems. While these problems have caused a great deal of trouble in the past, they are being solved by manufacturers, installers and various research teams across Canada.

The University of British Columbia, British Columbia Research Council and many others are involved in basic combustion and safety research, product performance evaluation, product development and market evaluation relating to NGV. Important refinements are expected to result in the future from this research.

The Government of Canada has supported extensive NGV research and development work in Canada, about $4 million in total. British Columbia and Ontario have contributed $800,000 and $200,000, respectively.

### 2.6.1 On-Board Fuel Metering Developments

The basic Italian regulator and mixer system was designed for the relatively warm Italian weather and also for smaller 6- and

TABLE 2.4

FUTURE NGV SERVICE STATIONS

**Alberta**

Husky Oil Marketing
561 - 15 Street, South
Medicine Hat, Alberta

Husky Oil Marketing
50th Ave. & 50th St.
Vegreville, Alberta

Husky Oil Marketing
Airdrie Shopping Centre
Airdrie, Alberta

**British Columbia**

Farwest Business Limited
4904 Highway 16, West
Terrace, B.C.
Contact: A. F. Zaharko

Preston Chev-Olds
19990 Langley By-Pass
Langley, B.C. V3A 4T1
Contact: David Scofield

Husky Oil Marketing
19811 Fraser Highway
Langley, B.C.

Petro Canada
9625 King George VI Highway
Surrey, B.C.

Shell Canada
9900 King George Highway
Surrey, B.C.

Shell Canada
3051 Lougheed Highway
Coquitlam, B.C.

Shell Canada
435 Burnette Avenue
New Westminster, B.C.

Husky Oil Marketing
21592 Lougheed Highway
Maple Ridge, B.C.

Petro Canada
1509 Main Street
North Vancouver, B.C.

Shell Canada
2103 W. Broadway
Vancouver, B.C.

Shell Canada
912 Clark Drive
Vancouver, B.C.

Gulf Station
Vancouver International Airport
Vancouver, B.C.

Esso Petroleum Canada
3965 North Road
Burnaby, B.C.
Contact: J. A. Stewart

Shell Canada
4505 Canada Way
Burnaby, B.C.

**Ontario**

CNG Fuel Systems
3070 Dufferin Street
North York, Ontario
M6A 2S6
Contact: Michael Hayvren

CNG Fuel Systems
Shell Rapidlube
Dixie Road
Mississauga, Ontario

CNG Fuel Systems
Skyline Shell Service Station
627 Dixon Road
Rexdale, Ontario
M9W 1H7
Contact: Michael Hayvren

FIBA Canning Inc.
2671 Markham Road
Scarborough, Ontario
Contact: Hugh Canning
V.P. and General Manager

Shell Canada & Union Gas
Devonshire Plaza
Windsor, Ontario

CNG Fuel Systems
2268 Princess Street
Kingston, Ontario

Shell Canada & Union Gas
London, Ontario

**Quebec**

CNG Quebec
2150, boul. Pie IX
Montreal, Quebec

127187 Canada Ltd.
2620, Notre Dame
Montreal, Quebec
H3J 1N1
Contact: B. Ettinger

Esso Petroleum Canada
1030 Mountain Street
Montreal, Quebec
H3G 1Y7
Contact: J. A. Stewart

Esso Petroleum Canada
8125, Cote de Liesse
St. Laurent, Quebec
H4T 1G5
Contact: J. A. Stewart

CNG Quebec
6505, Henri Bourassa
Montreal, Quebec
H1G 2V5
Contact: Michel Bougie

CNG Quebec
444, rue Lafleur
Lasalle, Quebec

CNG Quebec
412, boul. Lasalle
Verdun, Quebec

CNG Quebec
8015, Henri Bourassa
Montreal, Quebec

CNG Quebec
338, boul. Taschereau
Montreal, Quebec

CNG Quebec
200, Chemin Cote Vertu
Saint Laurent, Quebec

CNG Quebec
1625, boul. St. Martin
ouest
Laval, Quebec
Contact: Michel Bougie

CNG Quebec
360, boul. Wilfred Hamel
Ville Vanier, Quebec

SOURCE: Energy, Mines and Resources Canada, Natural Gas, "Canada's Transportation Fuel," Report TE-84-03, report prepared by John S. Noonan (Ottawa: Energy, Mines and Resources Canada, 1984).

4-cylinder engines common on Italian roads. When adapted to the larger 6-cylinder and V-8 engines common in Canada which, furthermore, have to start and operate at -40° Celsius, the systems consistently malfunctioned. For example, at very cold temperatures the original pressure regulator diaphragm proved to be too inflexible which resulted in improper fuel metering and stalling. That diaphragm was subsequently replaced with a type more suitable for Canadian cold weather operating conditions. Another problem resulted from adapting the Italian regulator system to larger engines such as typical North American V-8's with displacements of over 5 litres. Operating on much larger engines with different air flow characteristics, the original small Italian regulators were found to be non-optimal.

Various groups are now researching the design of a new regulator-fuel mixer system which will provide more reliable operation in Canadian conditions and greater fuel economy.[8]

Recent advancements in microelectronic (microchip) technology will allow the integration of this technology into carburetor and gaseous fuel regulators. Traditional designs are completely mechanical in nature and have not changed substantially for many years. The use of inexpensive electronic control systems is expected to improve systems control. Continued refinement of the system will improve components and may reduce the cost of the vehicle conversion over time although any cost reduction would probably be minor.

Although the vast majority of vehicles in the Canadian fleet are gasoline powered, and are thus candidates for conversion to NGV, many others are powered by diesel engines. Many high fuel consumption vehicles such as highway tractor transports use diesel engines. In fact, many of the most attractive target vehicles for conversion (e.g., commercial fleet vehicles) are diesel powered. Research and development work is continuing in Canada and elsewhere into adapting diesel engines to dual NGV-diesel systems. This is a more complex procedure with diesel engines because of their compression ignition nature. The complexity results from the high auto-ignition temperature of natural gas. In the most popular approach a pilot stream of diesel fuel is injected into the NGV fuel charge to initiate combustion. Optimum mixtures are considered to be 80 percent NGV and 20 percent normal diesel fuel, although this is difficult to achieve in practice. A 50-50 mixture is more common. Essentially, two separate fuel systems are thus required to operate a diesel engine satisfactorily.

Fiba-Canning Ltd. of Agincourt, Ontario is currently experimenting with a 4-stroke diesel-NGV conversion kit which may be available commercially in the spring of 1985. The kit is currently being tested on 18 different vehicles with engine displacements ranging from 8 to 14 litres. Results so far are claimed to have been very good. Fiba-Canning feels that their conversion kit installed on a 10-litre engine will sell for about $7,500.[9]

Mogas Fuel Systems of Vancouver offers for sale an Italian diesel-NGV conversion kit manufactured by Autosistema in Bologna, Italy. Current costs of conversion for a limited number of kits (approximately 10) is about $10,000 to $12,000 per vehicle.

DSMA Atcon Ltd. of Toronto and Fred Holmes Ltd. in Vancouver have been experimenting with diesel-NGV conversion kits for 2-cycle diesel engines (e.g., 6.2-litre Detroit Diesel engines). These may cost around $6,000.

Other groups experimenting with diesel/NGV conversions are Geosource Canada Inc. and B.C. Hydro. The British Columbia Research Council and G. Karim (P. Eng.) at the University of Calgary have been actively involved in studying the combustion of natural gas in diesel engines.

Experimental results show that rather than exhibiting a decrease in power output as gasoline engines do on NGV, diesel engines yield more usable torque and horsepower at high operating loads as well as reduced atmospheric emissions when using a diesel-NGV mixture of fuel.[10] However, at part-throttle loads the dual-fuel diesel is somewhat less efficient. Furthermore, some operators claim that total energy consumption is reduced by up to 9 percent on NGV-diesel although others report the opposite. Large-bore marine diesel engines have been successfully converted to run on natural gas boil-off on liquified natural gas (LNG) tankers. In fact, some 9 ferries of the British Columbia Ferries Corporation fleet may be converted to run on NGV in the near future. The Corporation plans to have the jumbo ferry Queen of Alberni converted for Expo '86.

In Saskatchewan a joint project between the Saskatchewan Power Corporation, the provincial Department of Science and Technology and Westank-Willock has resulted in the conversion of a John Deere 4440 diesel tractor and farm trucks to NGV on the John Fahlman farm near

Regina. Some problems have been encountered and a second generation diesel kit is at the development stage.

The various developments mentioned above will continue to increase the convenience and reliability of NGV while reducing fuel consumption and emissions. While several improvements may be feasible, along with the advent of diesel/NGV conversion kits, there is not likely to be a "breakthrough" in the on-board fuel delivery system.

### 2.6.2 On-Board Fuel Storage System

A serious practical problem associated with NGV is the much lower energy density relative to liquid fuels such as gasoline, propane or diesel fuel. While gasoline, diesel or even kerosene can be stored as liquids at room temperature in unpressurized containers, both propane and natural gas must be stored under pressure meaning that heavy-walled cylinders must be used. These cylinders, of course, contribute to a very safe fuel system but are heavy in weight. Propane is generally stored at a pressure of 1,700 kilopascals (kPa)--about 250 pounds per square inch. In contrast natural gas is normally stored as a compressed gas at a pressure of approximately 21,000 kilopascals (3,000 psi). This requires a very strong gas cylinder meeting certain rigorous standards. While these steel cylinders are virtually indestructible, they are very heavy. A cylinder which will hold the equivalent of 19.3 litres of gasoline equivalent in natural gas (at 21,000 kPa) is 60 litres in water capacity and weighs 62.5 kilograms.

To store the equivalent of 60 litres of gasoline in natural gas, 3 such cylinders would be required adding more than 187 kilograms (412 pounds) to the gross vehicle weight. However, at least 5 different sizes of cylinders are available which can produce minor savings in weight if the larger ones are used. To install that amount of NGV storage capacity in an intermediate size of vehicle would be difficult due to space limitations but would also add over 22 percent to the gross vehicle weight, reducing fuel economy and payload capacity in the process.

Considerable research effort has been directed at increasing on-board storage of NGV. Cylinder pressures above 21,000 kilopascals are considered to be impractical and uneconomic due to cylinder strength and compression requirements. One way to increase storage capacity without exacting the serious weight penalty associated with

steel cylinders is to build composite aluminium cylinders. These cylinders are produced from lightweight aluminium alloy and wrapped with an epoxy/fiberglass composite fabric for added strength and rigidity. These cylinders weigh only 60 to 70 percent of an equivalent steel cylinder and can withstand a pressure of 69,200 kilopascals (providing a safety factor of 250 to 300 percent).[11] A considerable weight saving is effected with these cylinders over their steel counterparts so payload capacity and fuel economy would not be as adversely effected. These components are spin-off products of the American space program and as such tend still to be relatively expensive. High volume production might reduce these costs substantially. The reduction in weight does not compensate for the additional volume requirement of the NGV storage system which may cause a problem in some vehicles, especially small cars.

A recent development in storage media is the use of adsorbants in fuel cylinders to increase storage capacity. By filling the tank with activated carbon or zeolites, about 3 times the empty cylinder capacity is achieved at low pressures only (activated carbon seems to be the most effective).[12] This increase in low pressure capacity is achieved with a considerable gain in weight due to the adsorbent fill (by a factor of perhaps 2) and a considerable increase in cost. The main advantage of adsorbent filled tanks is that a significant amount of natural gas can be stored at much lower pressure reducing compression requirements. Table 2.5 provides estimates made by Ford Motor Company of the characteristics of 3 types of storage systems.[13]

Option 1, shown in Table 2.5, stores as much NGV as Options 2 and 3 but at much lower pressure and considerably more volume. This reduces the compression requirement considerably. However, these adsorbent filled cylinders are generally viewed as being impractical and uneconomic at the present time.

It should be noted that some vehicles have been operated on liquified natural gas (LNG). In fact, the Atlanta Gas Light Company has experimented with up to 100 LNG vehicles in their fleet. This does increase the energy density by converting the gas into a liquid but it does so at a high cost. The LNG on-board storage tank is of a cryogenic type (insulated to allow very low internal temperatures) which is expensive to manufacture. Furthermore, pressure build-up must be released periodically, which vents natural gas to the atmosphere--a potentially very dangerous situation. For these reasons LNG is

TABLE 2.5

COMPARISONS OF ON-BOARD EQUAL CAPACITY STORAGE SYSTEMS[a]

| Property | Option 1[b] | Option 2[c] | Option 3 |
|---|---|---|---|
| Storage Pressure (MPa) | 2.17 | 7.0 | 16.65 |
| Storage Volume ($m^3$) | 0.232 | 0.170 | 0.062 |
| Storage System Weight (kg) | 186 | 65 | 52 |
| Storage System Cost (1983 U.S.$) | 1000[d] | 480 | 440 |

SOURCE: Amos Golovoy and Roberta J. Nichols, "Natural-Gas-Powered Vehicles," Chemtec, June 1983, p. 363.

[a]Fuel Capacity 8.2 kilograms natural gas, driving range (assumed 12.7 kilometres per litre gasoline equivalent) 161 kilometres.

[b]Option 1 is a low pressure storage system using 112 kilograms of activated carbon adsorbent.

[c]Options 2 and 3 make use of higher pressures but the cylinders are not filled with adsorbent.

[d]Includes the cost of carbon at $3.30 per kilogram.

generally viewed as being expensive and impractical for most road vehicles. In fact, Atlanta Gas Light has recently converted all LNG vehicles to NGV. However, research in this area continues. LNG is practical for marine use and possibly rail use.

### 2.6.3 Stationary Compression Systems

Currently marketed on-board storage systems are fully charged at 21 megapascals of cylinder pressure. This level of pressure is higher than TransCanada Pipeline Limited's main line pressure (4 to 8 MPa). Boosting the usual urban distribution pressure (35 kPa) to this level requires considerable compression. High quality compressors capable of delivering adequate quantities of NGV are costly. The estimate of installed cost for a typical retail service station in Canada is about $225,000 (current dollars).[14] This is a major cost to the retailer in comparison to a propane installation which can be had for about $25,000.[15] Most of the NGV compression station cost is attributable to the heavy duty compressor which must raise pressure from inlet to output by a factor of 600:1 in urban areas.

There may be significant savings in refueling station investment available if delivery pressure in gas distribution mains can be economically raised to 700 kilopascals (100 psi). This would ease the compression requirement. Most replacement distribution mains are of intermediate pressure, about 350 to 400 kilopascals (50-60 psi).

The original NGV compressors were produced in Italy by Idromeccanica. These are multi-stage, hydraulic units. Standard air compressors were also used but generally with poor results. Currently, there are several different sizes of compressor systems available in North America produced by different companies such as CNG Fuel Systems of Brampton, Ontario and Dual Fuel Systems, Inc. of Montebello, California. Some of these compressor packages utilise compressors made by a variety of companies.

Although this modern generation of NGV compressors works much better than the first generation, there are still mechanical problems to be sorted out. Furthermore, improvements to current designs are evolving and being incorporated. Some of these improvements will have the effect of reducing the cost of the compression system and others will improve reliability, safety or longevity.

The widespread distribution of natural gas has led to suggestions of home refueling systems for NGV. Small compressors with capacity adequate to slowly refuel 1 or 2 vehicles overnight could be installed and operated at individual residences. The only major barrier to this innovation is the cost of the installation. Natural gas is delivered to residential consumers at very low pressures, necessitating high compression requirements. If a low pressure on-board storage system could be devised then the compression requirements, and thus cost, could be reduced. Current cost estimates ($7,000) suggest that these types of home-refueling compressors are not viable.[16,17] Research continues in this area.

## 2.7 Detailed Review of NGV Incentives and Relevant Policies

### 2.7.1 Incentives in Canada

#### 2.7.1.1 Federal Government Grants

Under the mandate of the National Energy Program the federal government implemented the Natural Gas Vehicle Program in February 1983 which runs to March 1987. (The CNG Demo Program operated prior to this.) Acknowledging the high cost of converting vehicles to NGV, this program offers a grant of up to $500 per vehicle conversion, or towards the purchase price of a new NGV vehicle. While only new equipment costs involved in the conversion are eligible, and not labour or used equipment costs, both private and fleet vehicles are eligible. Vehicles converted can be either dual-fuel or dedicated to NGV. The grant is determined by dividing the total new equipment costs involved by two and granting this amount up to $500. To collect the full $500, equipment costs must be at least $1,000. These grants are taxable in all cases and generally are not available to provincial government departments or Crown corporations.[18] The Federal Propane Vehicle Program provides an $1,000 per vehicle grant to federal departments and Crown corporations such as Canada Post which convert their vehicles to either propane or natural gas.

Federal assistance is also available under the Natural Gas Fueling Station Contribution Program to operators of service stations who wish to install NGV compression and dispensing equipment. A total of 125 grants of $50,000 each will be made available to reduce the approximately $225,000 total cost of installing NGV equipment.

This program was implemented in May 1982 and runs to March 31, 1987. These contributions are also taxable and are only available to operators who retail NGV to the public.

The federal government also provides an incentive for the use of NGV by making the accelerated capital cost allowance available to NGV investments. Energy, Mines and Resources Canada is the leading supporter of research and development of NGV systems in Canada. For the record, the federal government also offers assistance to those who convert vehicles to propane although the maximum grant available is only $400. This program terminates March 31, 1985.

#### 2.7.1.2 Provincial Government Grants

The attitude of provincial governments to NGV varies widely in Canada from very enthusiastic to indifferent. Table 2.6 provides a matrix of provincial and gas utility incentives which are important in aiding the attractiveness of NGV. Quebec does not levy a sales tax on NGV although it does tax auto-propane at normal gasoline rates (30 percent). Manitoba taxes auto-propane and although no NGV is sold there, it has not yet officially waived fuel sales taxes on it.

In British Columbia, the province offers a $200 conversion grant and is planning to convert its own vehicles. Sales tax rebates in Ontario form the most generous incentive in Canada. The rebate on a new $15,000 vehicle would be $1,050 in that province.

#### 2.7.1.3 Utility Grants

Many gas utilities in Canada are faced with declining loads in traditional markets due to conservation and are actively seeking other markets for their product. NGV is one such market which many are exploring. Table 2.1 has shown that the gas utility fleets alone have been responsible for over 500 NGV conversions. Substituting NGV for gasoline reduces their own costs and also serves to advertise NGV to other parties. Table 2.6 provides a breakdown of the utility incentives currently offered. This table shows that there is no consistent pattern of incentives from province to province. Alberta and Saskatchewan offer no incentives (other than fuel sales tax exemption), while in Quebec up to $700 per vehicle is granted by Gaz Metropolitain. [Gaz Metropolitain offers a varying grant: $450 per vehicle (1 to 10), $550 per vehicle (11 to 20), $700 per vehicle (21 to 35), to a maximum of

TABLE 2.6

PROVINCIAL GOVERNMENT AND UTILITY NGV INCENTIVES[a]

| Province or Utility | Fuel Sales Tax (percent) | | | Conversion Grant ($Cdn.) | | Low Interest Loan | | Provincial Vehicles Converted to End of 1984 | |
|---|---|---|---|---|---|---|---|---|---|
| | NGV | Propane | Gasoline | NGV | Propane | NGV | Propane | NGV | Propane |
| Alberta | 0 | 0 | 0 | - | - | - | - | 0 | 10 |
| British Columbia | 0 | 0 | 20 | 200 | - | - | - | 870 | 0 |
| B.C. Hydro | - | - | - | - | - | - [d] | - | 70+ | 0 |
| Ontario | 0 | 0 | 20 | - [c] | - [c] | - | - | 0 | 0 |
| Union Gas | - | - | - | - | - | - | - | 225 | 0 |
| Consumers' Gas | - | - | - | 500[b] | - | - | - | 150 | 0 |
| Quebec | 0 | 30 | 30 | - | - | - | - | 0 | 0 |
| Gaz Metropolitain | - | - | - | 450-700 | - | - | - | 250 | 0 |
| Saskatchewan | 0 | 0 | 0 | - | - | - | - | 0 | 0 |
| Sask. Power Corp. | - | - | - | - | - | - | - | 16 | 0 |

[a]Exclusive of $500 federal grant. All grants are taxable. The Government of British Columbia is committed to converting all suitable vehicles in its fleet to NGV at the rate of 870 per year for 5 years.

[b]First 100 vehicles only.

[c]Ontario provides a full sales tax rebate on new vehicles converted within 90 days of purchase. Otherwise only on the cost of the equipment and labour.

[d]B.C. Hydro has recently replaced its interest free $500 loan with a low interest (9 percent) loan for the balance of the conversion costs after federal and provincial grants.

$24,500 per fleet.] Ontario provides a sales tax rebate on all NGV and propane equipment or vehicles while Consumers' Gas has provided a $500 grant to the first 100 vehicles converting to NGV.

These systems of sales tax rebates, conversion grants and interest free loans can combine to produce a very attractive conversion investment. In Quebec, for example, the $500 federal grant along with the maximum Gaz Metropolitain grant of $700 reduces the conversion cost of $2,500 per vehicle to $1,300. A fuel price spread of 20 cents per litre would allow a taxi to pay this back (assuming 80,000 km/yr of driving, and 20 litres/100 km) in only 5 months. Alternatively, in Alberta the same investment would take a full year to be recouped because only the federal grant is offered.

### 2.7.2 Incentives in Italy

As indicated in Section 2.2 a significant price differential has existed in Italy between gasoline prices and NGV prices and is currently widening. This differential, as in Canada, is the major stimulus for conversion to NGV fuel. The current Italian situation is different from Canada's. Because of the long-standing use of NGV in Italy, it does not need to be proven to the public, it is already the choice of many. Government and utility incentives are not offered for conversion.

### 2.7.3 Incentives in New Zealand

#### 2.7.3.1 National Government

The NGV situation in New Zealand is similar, although more advanced relative to Canada's. For a number of years the Government of New Zealand has been committed to encouraging New Zealand motorists to convert their vehicles to NGV from gasoline. To this end the Alternative Fuels Directorate of the Ministry of Energy and the CNG Publicity Committee have mounted a high profile publicity compaign to inform motorists of the benefits and costs of converting. A plethora of publicly distributed pamphlets describe all aspects of the NGV situation with many references to successful existing conversions.[19] Emphasis is placed on the potential savings accruing to motorists who convert to NGV.

Besides providing basic information to the prospective NGV customer, some of these government pamphlets show the individual not

only how to calculate the payback of the conversion investment but also the net present value and the internal rate-of-return relevant to the investment. A New Zealand government audio-visual presentation entitled "CNG--An Economic Alternative" is also available for general audiences. Furthermore, to provide an example to others, the government has implemented a policy aimed at converting all of its own suitable vehicles to NGV. As of August 1983 about 4,300 conversions of government vehicles had been done.

While the government does not own any retail NGV refueling stations, it does provide, in pamphlet form, a comprehensive listing of all NGV stations in New Zealand. This periodically updated list provides the names, addresses, telephone numbers and hours of business of all stations as an aid to motorists identifying refueling locations.

Beyond the above noted publicity measures the government has given assurances that the price of NGV will not exceed approximately half the price of gasoline. It has also assured motorists that taxation regimes will not be changed to the detriment of NGV vis-a-vis imported fuels.

Several monetary incentives are offered to attract NGV conversions besides the fuel price spread guarantee. For certain classes of vehicles (mainly commercial and farm) the road user tax is refunded in its entirety. However, for vehicles subject to a road fuel tax levied at the pump, there is no refund available.

A system of vehicle conversion loans are offered to cover the total cost of conversions from diesel or gasoline to NGV, propane or compressed biogas (CBG). The loan must be between $500 and $5,000, with interest charged at 10 percent per year. The term of the loan can not be longer than the payback period of the conversion investment (maximum 36 months). These loans are available to any individual or company.

Grants are also made available for conversions. These amount to $150 per conversion kit and are paid to wholesalers. A government grant is available for service station operators who wish to build and operate NGV refueling stations. These are cash grants of up to 25 percent of station development costs. Low interest loans are also available for station development ($5,000 to $500,000). Here again the Ministry of Energy has provided a wealth of information to prospective

operators and made the decision process as easy as possible by publishing "A Guide to the Establishment of a CNG Refuelling Station."

2.7.3.2 Gas Utilities

The NGV industry in New Zealand provides 150 free natural gas vouchers with each conversion (only new equipment is eligible) to natural gas. These vouchers provide entitlement to $2.00 worth of NGV per refueling ($300 in total).

2.7.4 Incentives in the U.S.

The American NGV market was described in Section 2.4 as being fairly small, characterised by mainly gas and electric utility and general fleet interest. The only private incentive to convert to NGV (CNG in the U.S.) is the fuel price differential noted in the above section to be about 30 to 50 percent. No grants or low-interest loans are available to individuals or operators and little information is provided at the federal or state level. Companies in the business of converting vechicles to NGV provide information regarding their equipment, and the benefits and costs without aid.

The major distributor of conversion and compression equipment in the U.S. is Dual Fuel Systems of Montebello, California. To date they have marketed approximately 20,000 conversion kits in spite of some fairly serious disincentives which exist in the U.S.

A recent study prepared for the National Aeronautics and Space Administration (NASA) has shown that the following barriers tend to discriminate against American NGV use (see Exhibit 2.1).[20]

(1) Safety related institutional barriers.

(2) Environmental Protection Agency tampering enforcement policy.

(3) Federal energy regulatory commission sale-for-resale restrictions.

(4) State sale-for-resale restrictions.

(5) State environmental protection laws.

(6) Road use taxes.

EXHIBIT 2.1

U.S. BARRIERS TO NGV USE: SUMMARY OF FINDINGS

| Barrier Number | Barrier | Effects | Recommendations |
|---|---|---|---|
| 1 | Lack of national safety standard | Uncertainty about acceptable design and use criteria<br><br>Many and varied regulations at the state and local levels | Adoption of NFPA[a] or other appropriate standards by federal, state and local agencies after resolving possible conflicts with existing federal regulations<br><br>Development of a parallel standard for LNG |
| 2 | Excessively conservative or misapplied state and local regulations, including:<br><br>- bridge and tunnel restrictions<br>- restrictions on types of vehicles that may be converted<br>- zoning regulations that effectively prevent natural gas refueling station installations<br>- application of LPG standards to LNG<br>- parking restrictions<br>- unsafe vehicle or refueling station requirements | Unsafe installations<br><br>Unnecessarily expensive installations<br><br>Inconvenience to users and potential users<br><br>Requirements to educate local authorities<br><br>Problems must sometimes be taken before city councils or courts for resolution | Adoption of NFPA or other appropriate standards by federal, state and local agencies after resolving possible conflicts with existing federal regulations<br><br>Development of a parallel standard for LNG |
| 3 | Need for clarification of EPA's[b] tampering enforcement policy | Marketers of natural gas vehicles systems, and potential users, may not know whether natural gas vehicles violate EPA requirements<br><br>Marketers of natural gas vehicles are not aware of all alternatives for satisfying EPA requirements | Update the EPA policy to reflect all alternatives for meeting EPA requirements and to eliminate ambiguity |
| 4 | The U.S. EPA vehicle standard for hydrocarbons | If tested outside of California, natural gas vehicles, though generally emitting less reactive hydrocarbons than gasoline vehicles, have difficulty meeting hydrocarbon standards because of their relatively large emissions of non-reactive hydrocarbons | Develop and implement a non-methane hydrocarbon standard for use as an alternative to the current standard |

EXHIBIT 2.1 (Continued)

| Barrier Number | Barrier | Effects | Recommendations |
|---|---|---|---|
| 5 | Uncertainty concerning state utility commission jurisdiction | Potential refueling station operators do not know whether they will be regulated by state utility commissions as public utilities | Systematic effort to identify states where public refueling stations would be subject to state regulation, and modification of appropriate state law |
| 6 | Sale-for-resale prohibitions at the state level | Potential non-utility refueling station operators may be prevented from installing a refueling station when the fuel is to be resold to fleet operators or the public | Systematic effort to remove state regulation and clauses in utility contracts that would prohibit customers from establishing refueling stations |
| 7 | Ambiguities in manufacturer warranties leave open the question of whether or not warranties on converted vehicles will be honoured | While not a barrier to the many fleet operators who perform their own warranty work, this can be a barrier to operators of small fleets who are left uncertain about what repairs will not be honoured | Accumulation of experience in working with natural gas vehicles at both the dealer and manufacturer levels. Manufacturers should also consider issuing more definitive statements on type of repairs that would not be covered by the warranty |
| 8 | Road use taxes in South Dakota result in substantially higher fees for CNG users than for gasoline users in some cases | Users of CNG vehicles may pay higher road use taxes than gasoline vehicle users, and potential users of CNG vehicles may be discouraged by the higher fees | Replacement of the current fee system for CNG vehicles at rates more similar to those for gasoline vehicles |
| 9 | State road use tax regulations often do not provide a factor for converting natural gas to gasoline equivalent units | Potential users of natural gas are uncertain about what amount of tax they will pay | Research is needed to develop an appropriate natural gas to gasoline conversions factor to be used by the states |

SOURCE: Jan Jablonski, et al., Assessment of Institutional Barriers to the Use of Natural Gas in Automotive Vehicle Fleets, Report DOE/HASA/0295-1 (Washington, D.C.: U.S. Department of Energy, August 1983).

[a]National Fire Protection Association (NFPA).
[b]Environmental Protection Agency (EPA).

(7) Insurance.

(8) Vehicle manufacturer warranties.

To the extent that many Canadian regulations and standards are modeled on the relevant American ones, many of these barriers to the use of NGV in the U.S. are relevant to Canada.

## 2.8 Summary

The various stages of market development in Italy, New Zealand, the United States and Canada have been described in this chapter. The use of NGV is very advanced in Italy relative to that in the other 3 countries, but New Zealand is catching up quickly. Italian and New Zealand transportation fuel markets are not strictly comparable to North American markets because of different taxation and energy supply histories. Traditionally, transportation fuels have been relatively expensive in Italy and New Zealand. Each of those countries has been at the mercy of the international oil market with no indigenous petroleum reserves. As technology developed and NGV systems became available, the use of natural gas in the transportation sector became common. Security of supply and low relative natural gas prices were, and still are, 2 important reasons for use of NGV there.

Alternatively, in Canada, and to a somewhat lesser extent in the U.S., gasoline prices have been relatively low and supplies in abundance. This, of course, has changed over the last decade. Thus, a market for NGV has developed in the U.S. and Canada. This expanding market and a large potential market has led to demands for a better NGV delivery system. As was noted in Section 2.6 a great deal of research is being devoted to improving NGV technology to make the fuel more compatible with Canadian climatic conditions and more vehicles in the Canadian fleet.

In Section 2.7 incentives provided in the 4 countries by the NGV industry and governments were reviewed. It was found that the financial incentives available to Canadians, especially in Quebec, Ontario and British Columbia, are substantial.

**Footnotes**

[1]Pietro Magistris and Gustavo Bonvecchiato, "Compressed Natural Gas Distribution System in Italy," Nonpetroleum Vehicular Fuels II (Chicago, Illinois: Institute of Gas Technology, November 1981).

[2]Pamphlets supplied by New Zealand Ministry of Energy, March 1984, and Canadian Gas Association, "Natural Gas Vehicle Bulletin," February 1985.

[3]B. Schlesinger, "Economic Comparisons of Methane and Alternative Vehicular Fuels," Nonpetroleum Vehicular Fuels II (Chicago, Illinois: Institute of Gas Technology, November 1981).

[4]Energy, Mines and Resources Canada, "Propane Vehicle Grant Program" (Ottawa: Supply and Services Canada, 1983).

[5]G. A. Constable, "Alternative Transportation Fuels: An Economic Comparison," Alternative Transport Fuels (Calgary: Canadian Society for Chemical Engineering, March 1982).

[6]Canadian Gas Association, "Natural Gas Vehicle Bulletin," April 1984.

[7]"Petroleum Marketing Report," Oilweek, June 27, 1983.

[8]CNG Fuel Systems Ltd. is currently conducting research in Detroit into improving the entire NGV system but is interested in particular in designing a new regulator to overcome some of these difficulties.

[9]There are about 20 diesel-NGV trucks operating in Canada. For example, B.C. Hydro operates a 5-ton truck powered by a converted 3208 Caterpillar diesel. This conversion has been highly successful. Manitoulin Transport in Ontario operates a converted highway tractor.

[10]G. A. Karim, "Methane and Diesel Engines," Methane, Fuel for the Future, edited by Patrick McGeer and Enoch Durbin (New York, New York: Plenum Press, 1982), p. 127.

[11]Amos Golovoy and Roberta J. Nichols, "Natural-Gas-Powered Vehicles," Chemtec, June 1983, p. 361.

[12]Ibid., p. 362.

[13]Ibid., p. 363.

[14]Energy, Mines and Resources Canada, "Communique," February 1983.

[15]Energy, Mines and Resources Canada, Personal Communication.

[16]Robert P. E. Axworthy, "The Home Rechargeable Natural Gas Commuter Car," Nonpetroleum Vehicular Fuels II. (Chicago, Illinois: Institute of Gas Technology, November 1981).

[17]Amos Golovoy and Roberta J. Nichols, "Natural-Gas Powered Vehicles," Chemtec, June 1983, p. 362.

[18]Energy, Mines and Resources Canada, Natural Gas: An Alternative Transportation Fuel, Cat. No. M27-54/1983 (Ottawa: Minister of Supply and Services Canada, 1983).

[19]New Zealand, Ministry of Energy, CNG Information (Wellington: Secretary of Energy, Private Bag, 1983).

[20]Jan Joblonski, et al., Assessment of Institutional Barriers to the Use of Natural Gas in Automotive Fleets, Report DOE/NASA/0295-1 (Washington, D.C.: U.S. Department of Energy, August 1983).

# Chapter 3

## REVIEW OF MARKET PENETRATION FORECASTS

### 3.1 Energy, Mines and Resources Canada's Perspective

Section 2.5 provided an outline of the current market status of NGV in Canada. About 3,000 NGV vehicles are currently in use in Canada compared with about 120,000 propane vehicles. The federal Department of Energy, Mines and Resources (EMR) estimates that there could be about 25,000 vehicles powered by natural gas by March 31, 1987. This would be about 8 times the current population of 3,000.[1] To meet this target in the remaining 3 years, 27 vehicles per day must be converted to NGV. Statistics from the federal Natural Gas Vehicle Program indicate that only 99 vehicles were converted in July 1984 or just over 3 per day.[2] The average daily conversion rate since the start of the program (when the first applications were received) has been about 3.8 vehicles per day. Applying this rate to the period August 1, 1984 to March 31, 1987 would yield a total of about 6,000 NGV vehicles. Even doubling this rate of conversion (to 7.5 per day) produces an estimate of about 9,000 NGV vehicles by the end of 1987.

EMR has developed this objective with the following criteria in mind:[3]

- a significant substitution of natural gas in place of oil,
- ensure that the NGV industry remains viable, and
- an NGV infrastructure that would justify Original Equipment Manufacturer's (OEM) production of NGV vehicles.[4]

In 1983 Energy, Mines and Resources commissioned two separate studies to explore the potential for conversions to alternative fuels These are listed below.

(1) Energy, Mines and Resources Canada, Transportation Energy Division, "Prospects For Converting Commercial Fleets to Alternative Fuels," Report TE-83-10, report prepared by Optima Consultants (Ottawa: Energy, Mines and Resources Canada, March 1983).

(2) Energy, Mines and Resources Canada, Transportation Energy Division, "Compressed Natural Gas, Phase 1 Market Segments" and, "Phase 2, Sales Potential," Reports TE-83-8 and TE-83-9. Both were prepared by Patrick Brown Systems Limited (Ottawa: Energy, Mines and Resources Canada, March and April 1983).

The first report provides an analysis of the attitudes and perceptions of fleet managers in Canada towards the two main alternative fuels, propane and NGV. The conclusions of the study reveal that those people who have converted to either fuel are generally satisfied with the results.

Alternatively, among the sample of fleet managers who had not converted any vehicles, many were found to have misconceptions and many were unaware of the two alternative fuels. This tends to highlight the necessity of mounting a vigorous advertising campaign to make all fleet managers aware of alternative fuels and their benefits.

The second study reveals that many attractive fleet-conversion targets in Canada remain essentially untapped. That report provides the following reasons as to why conversions of vehicles to NGV will continue to be rather limited:

- The companies marketing Compressed Natural Gas have limited resources and cannot sustain a large-scale marketing effort.

- Many potential customers are either unaware of the possible benefits available to them from the use of CNG or they feel they do not have enough information to make a decision.

- Potential customers are skeptical about alternate fuels, CNG in particular, and want to "wait and see" before making a commitment. Their concern might range from "will the government continue to support it after a few years?" to "will there ever be enough fueling stations to make it practical?"

- Some conversion shops, and some of the equipment, do not meet high standards and do not inspire confidence.

- There is considerable doubt about the trend in future fuel prices, both gasoline and natural gas. Many customers wonder whether the present differential will continue over the years, particularly since a large part of retail gasoline and natural gas prices consist of various federal and provincial taxes.

> In summary, the market is developing slowly because of a combination of ignorance, and uncertainty. Added to this, of course, is an overall reluctance of both business and private individuals to incur capital costs in difficult economic times.[5]

Phase II of the EMR study "Compressed Natural Gas" provides estimates of the sales potential of NGV in Canadian fleets by quantifying the number of vehicles per customer. Commuter vehicles were generally ignored. (In New Zealand 70 percent of NGV vehicles are commuter.) The emphasis was instead placed on commercial vehicles which exhibit high mileage characteristics. A summary of the findings is presented in the following quote.

> The major potential for CNG use in commercial vehicles lies in two main areas:
>
> - a few larger fleets of varied vehicles operated by the three levels of government or by public utilities.
>
> - a very large number of much smaller fleets operated by individual businesses in the transportation, manufacturing, and construction industries, and to some extent in services and wholesale trade.
>
> Medium trucks, light trucks and vans, which are driven average commercial distances each year, will generally pay out the conversion cost in less than a year in all areas, and in less than six months in Quebec. Taxis will pay out in less than six months anywhere.[6]

The Best Markets

In view of the price differential between gasoline and CNG in Quebec, and the substantial number of suitable vehicles in Montreal, this would appear to be the most favourable market situation in Canada. Toronto, with substantial concentrations of vehicles, would be a close second, and Vancouver, third.

Not surprisingly, local transportation appears to be the prime target industry, because it has more vehicles per company, on the average, than other types of business. Fuel costs are, of course, also a prime concern of this industry. The construction industry also appears to be a good target, although vehicle mileages are probably not as high.

Finally, these estimates indicate very clearly the significance of government, particularly local government, vehicle fleets. If suitable arrangements could be made, such fleets offer excellent opportunities to create a fueling nucleus

around which marketing efforts to other potential users could be concentrated.[7]

What is of particular interest is the suggestion that local government fleets would be particularly useful in showing leadership and establishing a refueling nucleus to which other fleets would be drawn. Fleet operators may consider NGV conversions to be less risky if they see governments getting involved.

As noted in Chapter 1, high mileage vehicles which return to a fleet base each day are prime NGV conversion targets. Table 3.1 shows a fleet size distribution taken from CNG Sales Potential Phase II (opposite page 8). This indicates that there are large numbers of fleets of significant size in all regions of Canada, many of which may be suitable for conversion.

Table 3.2 provides a breakdown of "Target Markets in the Private Sector." This table clearly shows that in the Transportation, Communications and Utilities category there are fleets of a significant size which warrant further consideration for NGV conversion.

Although these EMR reports offer useful insights into the potential NGV fleet market it is important to realize that propane has already made significant inroads into this market and that it is continuing to gain converts at the expense of NGV.

Because of limited Canadian experience with NGV, the Department of Energy, Mines and Resources is monitoring the performance of the Black-Top Cabs fleet of natural gas vehicles in Vancouver. Some results have been published in "Use of Natural Gas By Black-Top Cabs, Vancouver B.C.," Second Periodic Report.[8] This report was conceived to monitor performance, economy, atmospheric emissions, operational problems, and any other parameters thought to be useful. A very comprehensive analysis of the fleets' performance was carried out with the results summarized in tabular form. This is the first comprehensive analysis of such a large NGV fleet in Canada and will be continued as more experience is gained. The results of this analysis suggest that operation of these vehicles on NGV is satisfactory, although some evolution of the system can be expected.

The following is a general comment from the EMR report regarding taxi drivers' perceptions of NGV vis-a-vis gasoline.

TABLE 3.1

CANADIAN "MOTOR TRUCK" FLEETS BY SIZE AND PROVINCE

| Fleet Size No. of Trucks | Province | | | | | |
|---|---|---|---|---|---|---|
| | Ont. | Quebec | B.C. | Alta. | Sask. | Man. |
| 2-4 | 945 | 123 | 461 | 502 | 189 | 119 |
| 5-9 | 1333 | 239 | 424 | 525 | 267 | 214 |
| 10-24 | 1,684 | 412 | 445 | 558 | 249 | 207 |
| 25-49 | 729 | 290 | 225 | 222 | 80 | 88 |
| 50-99 | 478 | 201 | 151 | 142 | 37 | 53 |
| 100-499 | 459 | 224 | 145 | 120 | 26 | 36 |
| 500+ | 90 | 48 | 34 | 28 | 4 | 19 |
| Number of Fleets in each Province | 5,718 | 1,537 | 1,885 | 2,097 | 852 | 736 |
| Est. Number of of Trucks in the Fleets | 221,726 | 95,642 | 71,846 | 66,261 | 18,111 | 27,550 |
| Percent of Total Trucks in Province | 27.27 | 24.15 | 16.00 | 14.50 | 6.63 | 15.31 |

SOURCE: Energy, Mines and Resources Canada, "Compressed Natural Gas, Sales Potential," Report TE-83-9, report prepared by Patrick Brown Systems Limited (Ottawa: Energy, Mines and Resources Canada, April 1983), p. 8.

TABLE 3.2

NGV TARGET MARKETS IN THE PRIVATE SECTOR

| Description | Toronto | Montreal | Vancouver | Calgary | Edmonton | Regina | Saskatoon | Winnipeg | Ottawa/HL |
|---|---|---|---|---|---|---|---|---|---|
| **Manufacturing** | | | | | | | | | |
| Estimated number of establishments | 6,290 | 4,983 | 2,009 | 544 | 627 | 142 | 159 | 900 | 335 |
| Total number of vehicles | 18,741 | 15,377 | 4,502 | 2,637 | 3,508 | 1,295 | 1,208 | 2,312 | 831 |
| Average number of vehicles | 3 | 3 | 2 | 5 | 6 | 9 | 8 | 3 | 2 |
| **Construction** | | | | | | | | | |
| Estimated number of establishments | 1,500 | 1,300 | 1,000 | 2,500 | 2,250 | 1,350 | 1,350 | 2,300 | 1,450 |
| Total number of vehicles | 12,921 | 9,534 | 7,353 | 5,489 | 10,238 | 2,074 | 1,970 | 2,970 | 2,449 |
| Average number of vehicles | 9 | 7 | 7 | 2 | 5 | 2 | 1 | 1 | 2 |
| **Transport, Communications, Utilities** | | | | | | | | | |
| Estimated number of establishments | 1,200 | 1,200 | 1,000 | 900 | 1,000 | 300 | 300 | 450 | 300 |
| Total number of vehicles | 28,443 | 27,167 | 15,737 | 9,249 | 10,350 | 3,456 | 3,283 | 10,609 | 5,391 |
| Average number of vehicles | 24 | 23 | 16 | 10 | 10 | 12 | 11 | 24 | 18 |
| **Trade** | | | | | | | | | |
| Estimated number of establishments | 24,000 | 20,000 | 10,000 | 4,000 | 4,100 | 1,150 | 1,000 | 4,000 | 4,600 |
| Total number of vehicles | 13,043 | 9,893 | 5,264 | 2,748 | 3,075 | 1,094 | 1,039 | 2,617 | 2,472 |
| Average number of vehicles | 0.54 | 0.49 | 0.53 | 0.69 | 0.75 | 0.95 | 1.04 | 0.65 | 0.54 |
| **Finance, Insurance, Real Estate** | | | | | | | | | |
| Estimated number of establishments | 3,000 | 2,000 | 1,000 | 800 | 800 | 200 | 200 | 640 | 150 |
| Total number of vehicles | 945 | 772 | 359 | 160 | 284 | 118 | 98 | 181 | 44 |
| Average number of vehicles | 0.32 | 0.39 | 0.36 | 0.20 | 0.36 | 0.59 | 0.49 | 0.28 | 0.29 |
| **Services** | | | | | | | | | |
| Estimated number of establishments | 30,000 | 28,000 | 14,000 | 10 000 | 9,500 | 1,500 | 1,300 | 5,500 | 6,000 |
| Total number of vehicles | 17,895 | 15,214 | 7,687 | 4 629 | 5,181 | 1,780 | 1,690 | 3,787 | 3,392 |
| Average number of vehicles | 0.60 | 0.54 | 0.55 | 0.46 | 0.55 | 1.19 | 1.30 | 0.69 | 0.57 |

SOURCE: Energy, Mines and Resources Canada, "Compressed Natural Gas Sales Potential," Report TE-83-9 (Ottawa: Energy, Mines and Resources Canada), p. 18.

> Overall, it is apparent that taxis give better performance on gasoline than NGV, but that the majority of drivers find most aspects of performance tolerable with either fuel. The poorest rating for NGV and the greatest differential of performance for gasoline is for acceleration. Questions relating to non-driving characteristics of the two fuels (starting, idling, fuel switching) do not indicate widespread problems with either fuel.[9]

It should be noted that the Canadian General Standards Board has proposed certain standards for NGV which will ensure that NGV motorists are able to obtain NGV and NGV service of a consistently good quality. The recommendations of the Subcommittee on Gasoline and Alternative Automotive Fuels are provided in Exhibit A.1. Also shown are other relevant standards for conversion of vehicles to NGV (see Exhibit A.2).

### 3.2 Provincial Perceptions and Forecasts of NGV Penetration

Provincial governments in Canada are concerned about reducing their own fleet operating costs by exploring alternative vehicle fuels such as NGV. They are also interested in encouraging alternatives in the general population if this is justified in their province. However, governments can also be interested in promoting alternatives for other reasons. British Columbia, for example, has large reserves of natural gas but little oil. It is therefore more interested than other provinces in promoting NGV.

Section 2.7.1.2 summarizes the systems of grants and interest-free loans which the various provinces currently have in place. Of those provinces where NGV is available, all except Manitoba provide a subsidy through waiving sales tax on the fuel, but only B.C. offers a cash conversion grant and Ontario a sales tax rebate on new vehicle sales. Although most of these provinces are monitoring the NGV situation, they do not have market penetration objectives yet, presumably feeling that this might be premature. The small numbers of provincial government vehicles which have been converted to alternate fuels indicate that most provinces outside of B.C. are not prepared to take an active leadership role in actually converting their own vehicles to NGV. Even at the local government level NGV conversions are not encouraging. What this may indicate is that governments, like many fleet operators, are not prepared to take the risk of converting to NGV now and are "waiting to see." For example, the City of Calgary

Mechanical Services Department has studied NGV and propane and has decided to convert vehicles to propane. They now have 2 propane powered pickups and will add 10 by year end. The City of Calgary Police Department has experimented with propane and NGV and for a combination of reasons has decided to convert all suitable vehicles to propane as budgetary limitations allow. They now have 40 out of 430 police vehicles running on propane. The Government of Alberta also has about 10 propane powered vehicles but none running on NGV.[10]

As mentioned above, the Government of British Columbia has a somewhat different perspective on the NGV market. In fact, to encourage conversion of vehicles to NGV in B.C. it has decided to embark on a major fleet conversion program. This program envisages conversion of 870 government vehicles per year for the next 5 years for a total of 4,350 vehicles.

### 3.3 Private Perceptions

Faced with small amounts of load growth in traditional markets, natural gas utilities are exploring the possibility of marketing natural gas for vehicles. Each NGV fleet vehicle, for example, is roughly comparable in annual load to one residential customer and for high mileage vehicles equivalent to about 1.5. Some distributing utilities have taken the lead by converting vehicles in their own fleet and converting fleet operators in their service areas. In particular, B.C. Hydro, Canadian Western Natural Gas, Union Gas and Consumers' Gas in Ontario, and Gaz Metropolitain in Quebec are actively soliciting fleet conversions in their areas. Although all have their own confidential perceptions of how the general NGV market will develop, most agree that the key to large scale development of NGV lies in convincing fleet operators to convert. It is too early to tell how well this effort will succeed. The utilities are offering a marketing program which includes:

- an information package,
- slide shows,
- vehicle demonstrations,
- station tours, and
- conversion of one or a number of fleet vehicles on a "try out" basis.

Generally, public enquiries regarding NGV are welcomed but not solicited. The larger utilities are devoting 1 of 2 individuals full time to market development. The utilities' own fleet commitment to NGV is shown by the numbers of vehicles that they have converted (Table 2.1).

Members of the various Canadian natural gas distribution utilities and the Canadian Gas Association (CGA), with substantial financial aid from EMR, have formed the NGV Marketing Committee to advance the use of NGV in Canada. By the end of the summer, 1984 an NGV Marketing Executive position had been created in the CGA, the first to hold the position being Mr. R. E. Corrigan. His responsibility will be to work with the NGV Marketing Committee to formulate a marketing plan to bring about faster and deeper NGV penetration in Canadian fleets.

### 3.4 Institutional Barriers to NGV Conversions

The previously documented benefits of natural gas for vehicles often outweigh the disadvantages. However, because NGV is a new fuel in a less than developed market in Canada, there are certain barriers to its widespread use. Although not explicitly intended to deter the use of NGV, safety regulations such as various Pressure Vessel Acts are intended to ensure the safety of the public as well as employees. In those instances where these types of regulations inadvertently inhibit the installation of NGV service stations or NGV in vehicles, some considerable effort may need to be expended to have inappropriate regulations either modified or rescinded. The utilities have been trying to do this. For example, one natural gas distributor in Ontario has experienced difficulty in obtaining exemption from the Pressure Vessel Act for NGV stations. A prime example of another institutional barrier is the difficulty the B.C. Ferry Corporation has encountered in obtaining Canadian Coast Guard approval to power ferries with NGV.[11]

These institutional barriers exist at both the provincial and municipal level complicating the approval process for NGV use.

Another type of institutional barrier which may inhibit adoption of NGV occurs at the vehicle manufacturer level. Warranties on new vehicles are very important to customers in case of defects in parts or workmanship. Manufacturers are understandably concerned about changes to vehicles made after the sale, such as addition of NGV equipment which may affect vehicle operation and reliability. As the

situation now stands, the installation of NGV equipment does not per se invalidate manufacturer warranties. However, if a problem does occur with the vehicle which the manufacturer believes was caused by or aggravated by the NGV components or use of NGV, the problem will not be covered under warranty. If the owner of a converted vehicle experiences premature valve seat recession due to the use of NGV, for example, the manufacturer would not perform repair work under warranty.

### 3.5 Summary

This chapter has been devoted to market development perspectives. While a rough goal of 25,000 vehicle conversions by the end of 1987 has been established by EMR, the current rate of conversions will have to rise to reach that goal. Estimates of the total potential for conversions indicate that up to 500,000 fleet vehicles from Quebec to British Columbia would be candidates, with many of these being very good targets for conversion.

While the NGV marketing effort varies greatly from one province to the next, with the most concentrated efforts being made in Quebec, Ontario and British Columbia, one would expect that conversions would be occurring at a much faster rate than they are. Chapter 4 indicates some reasons as to why this is not happening.

**Footnotes**

[1]Energy, Mines and Resources Canada, Personal communication, Summer 1984.

[2]Energy, Mines and Resources Canada, "Natural Gas Vehicle Grant Program," 1983.

[3]Energy, Mines and Resources Canada, "Compressed Natural Gas, Market Segments," Report TE-38-8, report prepared by Patrick Brown Systems Limited (Ottawa: Energy, Mines and Resources Canada, March 1983), p. 2.

[4]Ibid.

[5]Ibid., p. 6.

[6]Energy, Mines and Resources Canada, "Compressed Natural Gas, Sales Potential," Report TE-83-9, report prepared by Patrick Brown Systems Limited (Ottawa: Energy, Mines and Resources Canada, April 1983), p. 9.

[7]Ibid., p. 4.

[8]Canadian Resourcecon (1983) Limited, et al., Use of Natural Gas by Black Top Cabs, Vancouver B.C., Second Periodic Report, report prepared for Energy, Mines and Resources Canada, March 1984.

[9]Ibid., p. 83.

[10]Personal communication.

[11]Personal communication with B.C. Ferry Corporation representative.

# Chapter 4

## ISSUES IN NGV MARKET DEVELOPMENT

### 4.1 Intercountry Comparison

The four-country comparison of NGV market status provided in Chapter 2 shows that, although significant use is made of NGV in all four, marked differences exist among their respective markets. Such differences are observed in the stage of NGV market development, government attitudes and policies towards NGV vis-a-vis conventional fuels, and the degree of suitability of NGV as a long-term replacement for gasoline and diesel fuel. Contrasting the different situations places Canadian NGV policy in a perspective which may be helpful for determining whether public policy changes relating to NGV should be considered.

The Italian NGV market is probably the most developed and mature in the world. This has resulted from historically high relative gasoline prices and adequate indigenous natural gas supplies. However, indigenous supplies are declining forcing the Italians to rely on very expensive imported Algerian natural gas. This may have the effect of curtailing further NGV penetration in Italy. In fact, the Italian Government views natural gas use in transportation as a low priority.

Alternatively, NGV markets in the United States and New Zealand are in the early stages of development. In those countries the long-term supply of indigenous natural gas is adequate and imported supplies (at least in the U.S.) are expected to be secure and reasonably priced. The difference between these two foreign markets is, however, quite marked especially in government policies affecting market penetration of NGV. In the U.S. there is virtually no federal or state government encouragement to convert vehicles to any alternative fuel beyond normal market forces (accelerated capital cost allowance being the only exception). Further, there are no public NGV refueling stations in the U.S. and there has been no government encouragement to establish one. This is precisely the opposite of the situation in New Zealand.

As a result of the different approaches, 30,000 vehicles (exclusively fleet) use NGV in the U.S. Fleet vehicles, of course, are overwhelmingly the most attractive NGV conversion targets. The existence of significant barriers to NGV use in the U.S., as identified by the previously cited NASA Report, suggests that if these barriers were removed, NGV conversion would be more attractive in the U.S. Even with little government involvement and certain institutional barriers to penetration, a sizeable population of natural gas powered vehicles has been established in the U.S. As a share of the total U.S. vehicle population, NGV-powered vehicles remain only a small fraction of 1 percent.

In New Zealand a host of subsidies, lower conversion costs, a government guarantee that NGV will always be half the price of gasoline and extensive government supported public advertising have created a very favourable environment for conversions to NGV. This has resulted in a rapid increase in the number of fleet and commuter NGV vehicles in that country. As more supplies of indigenous natural gas are developed, New Zealand will be able to expand penetration of NGV into its transportation market. This will effectively reduce dependence on imported petroleum.

An evaluation of Canada's NGV situation vis-a-vis that of New Zealand and the U.S. points out some important differences. The most important is the New Zealand Government's guarantee that the price of natural gas for vehicles will always be half that of gasoline. There is no such guarantee in Canada or the U.S. This guarantee of long-term price differential stability provides decision makers with an ability to accurately forecast the benefits of converting to NGV. In Canada, the absence of such a price guarantee is causing fears that once NGV penetration is widespread, fuel taxation will eliminate or greatly reduce the price advantage NGV holds over gasoline. In fact, in the EMR reports referred to above, a concern mentioned by some fleet operators interviewed was uncertainty regarding future fuel price differentials. If the price differential between gasoline and natural gas were to close, the rationale for converting to NGV would be virtually eliminated. The current softness in the conventional fuels market and concomitant reductions in real gasoline and diesel prices have reinforced this concern. At the same time, it is difficult to see that the federal government would be prepared to make such a price differential guarantee while attempting to deregulate other energy markets.

Financial incentives to convert to NGV can take the form of low interest loans or grants or fuel purchase coupons as in New Zealand's example. In Canada conversion incentives are generous. In no other country is such a cash sum paid for converting to use a less expensive fuel. As well, the $50,000 refueling station grant is not equalled anywhere else. The system of incentives offered to convert in Canada, comprising the federal government grant and the various provincial and utility grants and sales tax rebates help to defray the conversion cost significantly. However, even with the grants, a sizeable conversion cost remains.

The government of New Zealand, in concert with the NGV retail industry has ensured that an average size car is always within one refueling of a public NGV station on the North Island. Obviously, this would be very difficult in Canada where station grants are intended to encourage their proliferation at least in high density traffic areas. The advent of a strong network of public refueling stations in Canada would probably encourage more private vehicle owners to convert. However, the compression facilities are so expensive that it will be difficult to persuade many station operators to incur the start-up costs if they are not assured of an adequate customer base to generate revenue. In some situations in Canada the opening of a new NGV station has "cannibalized" another station's customer base, thus reducing revenue to it, while not attracting enough converts to make the entrant profitable.

The Government of Canada publishes information through the Department of Energy, Mines and Resources in an effort to increase awareness of both NGV and propane. Members of the NGV industry are also attempting to increase public and fleet operator awareness of the benefits. However, the quantity of information available in Canada does not equal that made available in New Zealand at the NGV customer level.

The potential converter in New Zealand has access to a wide variety of publications from small pamphlets to in-depth studies of NGV. Government and industry go to great lengths to inform the public about the advantages, the costs, availability and "how-to-convert." In Canada, technical documents such as the recently released "Natural Gas, Canada's Transportation Fuel" are of high quality but are not aimed at the average fleet operator or commuter. Canadian information aimed at the ultimate NGV user is limited at this time but improving. The

situation is similar in the U.S. where the public is generally not informed about NGV.

This brief intercountry comparison of NGV market characteristics and policies indicates that no foreign markets for this alternative transportation fuel are identical to Canada's. The New Zealand and Italian NGV markets are basically "captive"--the only alternative fuel being relatively expensive conventional gasoline refined from imported oil. In the U.S., in spite of the need for imports to supplement indigenous supplies, gasoline and diesel fuel are perceived to be in adequate supply and are less expensive than in New Zealand or Italy. In Canada there has never been a shortage of gasoline or diesel fuel (contrary to U.S. experience) and supplies are not currently threatened. Natural gas is in abundant supply, but so is propane (Canada still exports about 30,000 bbls/day of propane). In addition to Canada's favourable supply situation for all fuels (in fact, Canada has even been a net exporter of crude oil during 1984), petroleum and, thus, its refined products have been selling for relatively less, due to the administered pricing system, than in most other countries. However, in 1985 Canada is expected to move to market determined prices.

### 4.2 Issues in Market Development

The earlier chapters of this report have enumerated the benefits and costs of utilizing NGV as a transportation fuel in Canada and elsewhere. In Section 4.1 characteristics of Canadian and foreign NGV markets were contrasted. Issues raised there help to identify reasons for the low level of penetration of NGV into the transportation fuels market. The point has been made that NGV is an excellent fuel, very abundant in Canada in its basic form and highly encouraged by financial incentives. Yet penetration remains low and has so far been greatly outstripped by propane penetration. The conditions seem ripe for a strong advance by NGV yet, on close inspection, a lengthy list of barriers can be identified. These include:

MAJOR

- Fuel Price Differential Uncertainty
- Conversion Costs
- Compression Costs
- Propane Competition
- Low Key NGV Marketing Effort
- Lack of NGV Refueling Stations

MINOR

- Barriers of an Institutional Nature
- Lack of Government Vehicle Conversion Commitment
- Technological Developments

While the major factors alone serve to dissuade many potential NGV converts, the minor factors serve as reinforcement. Each of these negative factors is discussed below, including suggestions as to how they might be mitigated through public policy and/or private industry initiatives.

4.2.1 Fuel Price Differential Uncertainty

NGV is significantly less expensive than gasoline on a litre equivalent basis. It will probably remain so for the foreseeable future in Canada. However, so are propane prices. Furthermore, gasoline and diesel prices have declined in real terms in most parts of Canada over the last 2 years (until the recent shift to world oil prices) reducing the competitive advantage of both NGV and propane. In 1985 new energy pricing agreements between the provinces and the Government of Canada will likely be signed. Although this may result in a lowering of natural gas prices (and thus NGV prices), it is not expected that a commitment by governments to keep NGV prices at (for example) 50 to 60 percent of retail gasoline prices will be forthcoming. This is a source of considerable concern for potential convertors to NGV because the relative fuel price differential is by far the most important incentive. This concern is complicated by the fact that a federal-provincial agreement may set the natural gas price but provinces may levy an ad valorem sales tax. Many have no doubt that when penetration of an alternative vehicular fuel becomes significant, a sales tax will be levied on it to compensate for tax revenue lost because of declining gasoline demand. This must be considered an eventuality. Uncertainty regarding relative fuel prices is probably the most important concern of prospective converts.

It is doubtful that anyone will be able to guarantee that NGV will be half the price of gasoline indefinitely, but the federal government could, as a matter of policy, state that the NGV price before road or sales taxes will be a specified fraction of the equivalent gasoline price for a specified time period. Alternatively, the federal government could increase its surcharge on gasoline for a stated long-term period.

Furthermore, it has been suggested that distributing utilities and TransCanada Pipelines Ltd. could offer a special rate on natural gas for use as a transportation fuel. This would greatly enhance the economic viability of NGV and increase the volumes carried by TransCanada. However, there has not yet been a move in this direction.

A related and important issue is the average proportion of disposable income or budget devoted to fuel expenditures. In countries where this is large, there is a greater incentive to switch to an alternate fuel. In Canada, the proportion of disposable income devoted to fuel expenditures is small, thus the incentive to convert is smaller.

### 4.2.2 Conversion Costs

Current vehicle conversion costs are about $2,500. The system of grants designed to make this cost less onerous does help, but in most provinces this does not reduce the cost to a trivial level. In Alberta, for example, $2,500 less the $500 federal grant still leaves the owner with a $2,000 per vehicle bill. A propane mono-fuel conversion (which costs an estimated $1,400) results in a bill of $1,000 per vehicle after the $400 federal grant. (This differential in no way implies that the propane equipment is less reliable or of lower quality.)

The absolute cost of conversions may be quite burdensome for some fleet operators who want to convert large fleets. The net after-grant cost of converting a fleet of 100 trucks in Alberta might be as high as $200,000 for example. An expenditure of this size might need to be spread over more than 1 or 2 years.

In British Columbia, B.C. Hydro now offers a low interest (9 percent) loan to pay the conversion costs not covered by the federal and provincial grants. This effectively removes the barrier of high up-front investment costs for convertors and is a measure which could be seriously considered in other provinces.

This raises the question of converting vehicles versus purchasing NGV dedicated vehicles. It has already been established that dedicated vehicles can increase the utilisation efficiency of NGV considerably and that the cost of a factory built dedicated vehicle will only be $600 or so above that of a standard gasoline powered

vehicle. This reduction in equipment cost would increase the attractiveness of NGV use. However, only one vehicle, a Ford Ranger truck, is produced in such configuration at present and it was an off production line, 37-vehicle experiment not representative of an optimized, long production run vehicle. A variety of body styles are demanded by consumers even if they want to use NGV. In order to minimize the vehicle NGV-associated costs, it would seem most advantageous to build dedicated vehicles to avoid duplication of on-board fuel delivery systems (i.e., gasoline-NGV). It will take some time before major manufacturers are able to offer a wide variety of these vehicles to consumers. Alternatively, the cost of conversion kits may be reduced through redesign and innovation, but the potential is probably for only small cost reductions.

One innovative way in which the cost of conversion could be lowered would be to have the NGV cylinders, the most expensive components, owned by the area natural gas distributing utility and leased by the vehicle owner. Because of the long life of these cylinders, they could be amortized over a 20-year period (or more). An arrangement of this sort would reduce the up-front conversion cost by over $1,000 to NGV convertors. Utilities already spend about $1,000 to 3,000 per house developing the residential market, so an expenditure on NGV cylinders would not be unreasonable. The utilities would include the cost of the cylinders in their rate base and lease rates would be based on the allowable rate of return established by the regulators. It would then be possible for both the utility and the vehicle operator to share in the fuel cost savings. However, at present some utilities have already decided against doing this.

The federal government could help to reduce conversion costs by offering duty and sales tax remission on the NGV cylinders and other equipment which must be imported into Canada at present. There is some indication that this will occur.

### 4.2.3 Compression Costs

Fleet operators who convert their fleets to NGV usually require an on-site compressor to supply NGV. These facilities can cost up to $300,000, although usually the cost would be less. When this is added to the vehicle conversion costs, a sizeable investment is required. Compression facilities to provide service at a public station would cost about $225,000. Few retail station operators have been willing to

spend this large a sum even with the $50,000 grant. Thus, reducing compression facility costs would be very helpful in reducing the total costs of NGV use. Industry sources suggest that reducing the station cost by $10,000 is equivalent to reducing the retail price of NGV by approximately 0.3 to 0.6 cents per litre.

A subsidiary issue is the reliability of the compression systems. New heavy duty compressors are much better than the earlier designs, but there are still problems which need solving. Reliability is of prime concern to operators. Successive redesigns and innovation may then reduce the cost of facilities significantly. This would be a very important development in NGV marketing. Unfortunately, increasing the reliability of the compression system may result in increased costs. Boosting service line pressures to stations would help reduce this cost.

### 4.2.4 Propane Competition

It is clear that propane is the only real competitor that NGV must overcome. Unfortunately for NGV, propane is a very tough competitor. The same advantages which are characteristic of NGV are shared by propane. Furthermore, propane has a few advantages not shared by NGV. These are:

- energy density closer to that of gasoline,
- lower vehicle conversion and dispensing costs,
- well established distribution system,
- greater public familiarity with propane, and
- more easily transported to remote locations.

Alternatively, propane, while a safer fuel than gasoline, is probably not as safe as NGV. If allowed to escape in the unlikely event of a tank rupture, propane will puddle on the ground due to its heavier-than-air nature. This will produce a very explosive mixture. Furthermore, it has a lower ignition temperature and a lower minimum flammability limit. NGV will quickly dissipate if accidentally released, making the likelihood of an explosion very remote. To put the safety issue in perspective, the fact is that very few gasoline powered vehicles are involved in mishaps resulting in fire; thus, increased safety of NGV is not a major selling point.

In fact, with either alternative fuel, gasoline is usually still carried aboard the vehicle, resulting in the same hazard for non-dedicated vehicles. Some poorly done NGV and propane conversions have created hazards due to fuel system leaks occasionally resulting in fires and injuries. As well as the above disadvantages of propane, it is not nearly as abundant in Canada as is natural gas.

4.2.5 Low-Key Marketing Effort

The Canadian NGV industry is composed of the natural gas distributors, distributors of equipment for NGV conversions and the fuel retailers (the public service stations). These groups all have a strong incentive to advance NGV penetration but to date no wide scale marketing effort has been launched. Instead, most of the effort has been concentrated in contacting fleet operators who are most likely to convert. A study conducted for Energy, Mines and Resources Canada, "Prospects for Converting Commercial Fleets to Alternative Fuels," reveals that a stepped-up marketing effort might be advisable since many fleet operators contacted were totally unaware of both propane and NGV potentials in their fleets. Certain groups such as GNC Quebec Ltee. based in Montreal, Consumers' Gas and Union Gas in Southern Ontario and B.C. Hydro are aggressively soliciting conversions in their markets. CNG Fuel Systems is also aggressively marketing equipment for conversion and compression. The Canadian Gas Association is trying to increase the marketing effort through the NGV marketing committee.

A subsidiary issue to making potential converters merely aware of NGV is providing enough information on the economical nature of NGV and assurances that it is, above all, a very safe and inexpensive fuel. This is extremely important.

4.2.6 Lack of Refueling Stations

The lack of a network of refueling stations in most major cities as well as across Canada is not necessarily a barrier to large fleet operators, but it certainly has been to commuters and smaller operators for whom a private compression station is not likely an option. As more NGV stations open, this will become less of a problem. In fact, in late 1984 and into 1985, there is scheduled to be a sizeable increase in the number of refueling stations open to the public.

### 4.2.7 Institutional Barriers

As discussed in Section 3.4, a lengthy list of barriers can act to impede NGV utilization. While a major effort to identify and quantify the effects of these barriers has not been attempted here, considerable effort has been expended by the industry and government. Work by EMR, the Canadian Gas Association (CGA) and the Canadian General Standards Board has gone some way to identifying and removing these institutional barriers and developing appropriate standards. Regulatory agencies and municipalities could play a significant role in removing these barriers and adopting new NGV standards without undue resistance. The CGA standards for NGV vehicles, equipment and compressor stations should be adopted in each province (see Exhibit A.2). However, it must be recognized that adopting appropriate regulations in all provinces where natural gas is available will take some time.

### 4.2.8 Lack of Government Vehicle Conversion Commitment

The substantial financial incentives offered by governments in Canada have typically not been matched by commitments to convert publicly owned vehicles to NGV. Only a few federal government vehicles have been converted to NGV (3,000 are running on propane) and in most provincial government fleets only 1 or 2 experimental vehicles are found. British Columbia is the exception. Recently British Columbia has made a strong commitment to NGV by implementing a program of conversion for almost 5,000 vehicles over a 5-year period. With financial aid from EMR some ferries in the B.C. Ferries Corporation fleet may be converted to natural gas in the future if regulatory approvals can be obtained.

Potential converters may question the apparent reluctance of governments to convert their own fleet vehicles while offering financial incentives to do so. (Crown corporations and federal government ministries are eligible for the $1,000 Federal Propane Vehicle Program grant.) Part of the reason for this reluctance is the fact that government fleet managers must also assess the value of alternative fuels to their fleets and they are just as risk averse as any other operator, a fact not always acknowledged by the public. Above all, conversion to NGV should be economically attractive to government fleets before they actually do convert suitable vehicles. Only in cases where operators are overly conservative (and there does appear to be evidence of this) is there cause for concern. The adoption of a

"wait and see" attitude is not very productive if there are large fuel cost savings to be made by utilizing NGV. A more proactive stance by government fleet operators might help to "seed" more fleets. A directive from the Treasury Board reinforcing the Federal Propane Vehicle Programs would be useful in convincing federal fleet operators to convert.

Industry and the federal government have made a very substantial research and development commitment to natural gas and, to a lesser extent, so have the governments of Ontario and British Columbia. Canadian technical literature now available represents some of the most advanced in the world (see Energy, Mines and Resources Canada study, TE-84-03, "Natural Gas, Canada's Transportation Fuel," authored by Mr. John S. Heenan). Furthermore, research and development in Canada will probably result in production of the most efficient and reliable system in the world.

Federal support by converting vehicles has been strong in the propane market but weak in natural gas. There needs to be a greater commitment to convert vehicles to NGV at both the federal and provincial level. This may improve in the near future as the results of trials with a small number of vehicles proves satisfactory. These commitments could be followed up by a national conversion program for all suitable government vehicles.

### 4.2.9 Lack of Technological Developments

Section 2.6 discussed the possible technological changes which may occur in the NGV industry. Although currently offered NGV systems generally work well, improvements will continue to be made. A second generation kit designed to work with electronic ignition systems will be available in the near future. Important advances will occur in NGV-diesel engine technology which will enable successful and economical operation of diesel engines on natural gas. This will enable a large section of the transportation fleet, which did not have the option of using this fuel, to take advantage of NGV. Reliable conversion kits for various 2 and 4-stroke cycle engines are scheduled to become available within a year or two. Other developments will result in safer and more dependable equipment. These developments will broaden the NGV market and enhance operating characteristics but it is not likely that great cost reductions will occur without compromising quality. The publication, "Natural Gas, Canada's Transportation Fuel," contains a comprehensive analysis of what types of NGV research and development are being addressed in Canada.[1]

**Footnotes**

[1]Readers interested in learning more about technological research and development and other NGV related matters should access the B.C. Research NGV Information Centre which contains upwards of 150 papers and articles. This can be done by contacting B.C. Research directly for access permission at the following address:

B.C. Research
3650 Westbrook Mall
Vancouver, B.C.
Canada V6S 2L2
Phone (604) 224-4331
Cable RESEARCHBC
Telex 04-507748

# Chapter 5

## CONCLUSIONS AND RECOMMENDATIONS

Natural gas is an excellent fuel for internal combustion engines. It has a very high octane rating, is clean burning, produces very low levels of atmospheric pollutants, is very abundant in Canada and consequently is priced much lower than gasoline or diesel fuel. These characteristics would seem to make it the fuel of choice for Canadian transportation. However, as shown in this report, penetration has been slow and conversions to NGV in 1984 have been far outstripped by conversions to propane.

For example, under the Federal Vehicle Conversion Programs, 113 vehicles were converted to NGV while 1,632 were converted to propane in the period October 1 to October 31, 1984.

As of summer 1984 about 3,000 NGV powered vehicles were in use in Canada while about 120,000 propane vehicles were being used.

An inter-country comparison in Section 4.1 indicated that the Canadian transportation fuels market is unique in several respects, such as low relative gasoline and diesel prices and an historical absence of fuel supply shortages. Canadians have been paying fuel prices significantly below world prices ever since the first energy price shock in 1973. As well, there has never been a fuel shortage in Canada even with lower oil prices than the rest of the world pays. The United States, for example, experienced gasoline shortages in the mid-1970s and natural gas shortages in the late 1970s.

Based on current and foreseeable energy prices, NGV is a logical choice for meeting many fleet fueling requirements. In spite of this, there are certain real and perceived obstacles to large scale penetration of NGV. Recommendations for actions which could mitigate these problems are summarized below.

### 5.1 Fuel Price Differential Uncertainty

This is probably the most significant source of risk in the conversion appraisal process. If potential convertors cannot be

reasonably sure of the fuel price differential, it is impossible to establish the value of converting a vehicle. Unfortunately, this uncertainty comes from both the federal and provincial levels. At least a temporary natural gas pricing commitment from both levels of government is required because many people are convinced that NGV will not be cheaper than gasoline over the long run.

### 5.2 Conversion and Compression Costs

The high cost of conversion kits and compressors is a barrier to many, even with the financial incentives currently offered. One viable way to reduce these initial costs would be for the gas distributors to offer leasing arrangements on certain expensive components such as the cylinders. Innovative ways of financing the expensive compressors could also be found to reduce the up-front cost for fleet operators. There may also be some potential for reducing equipment costs by successive engineering redesign. Distribution pipeline pressures could be increased where possible to reduce compression requirements and thus the cost. A duty and sales tax remission program could be implemented to reduce the cost of imported cylinders.

### 5.3 Propane Competition

Propane is and will continue to be a formidable competitor to NGV. Declining demand for propane as a heating fuel will mean propane will be in greater supply for transportation uses. Propane conversion costs are significantly lower than those for NGV, and propane fuel costs are also considerably lower than gasoline prices but higher than NGV prices.

### 5.4 Low-Key Marketing Effort

The NGV industry is relatively small in Canada and does not have funds adequate to mount a full scale advertising campaign in all areas. Distributors have been concentrating on contacting fleets--the most likely conversion targets. However, surveys cited in this report indicate that many fleet operators are still unaware of the NGV potential. Thus, more advertising might be useful. The recent establishment of an NGV Marketing Executive within the Canadian Gas Association will result in more information reaching the operators of suitable vehicles.

### 5.5 Lack of Government Vehicle Conversion Commitment

Government fleets have not been in the forefront of the NGV conversion movement. In fact, most have been very tentative about converting even a few vehicles on an experimental basis. Publicly-owned fleet vehicle managers should be encouraged to ensure that, as in the Government of British Columbia's example, all suitable government high-use vehicles are converted in a reasonable time period. This type of commitment might act as a fueling "nucleus" encouraging others with suitable vehicles to convert to NGV. There is some indication that this is improving. There are currently some 3,000 federal vehicles operating on propane. However, EMR is currently exploring the feasibility of a large purchase order of dedicated NGV vehicles for government and utility fleets. In an effort to expand NGV use, a seminar was held by EMR in October 1984 to demonstrate to federal fleet managers the benefits of converting their vehicles to NGV.

### 5.6 Lack of Refueling Stations

This problem is gradually being overcome as retail gasoline stations add NGV compression facilities. The natural gas distributors and oil company marketing departments are moving quickly to ensure that NGV is available publicly in many major urban areas and some smaller centres (essecially in Quebec and B.C.).

### 5.7 Institutional Barriers

Inappropriate barriers to NGV utilization can be removed with some effort. As mentioned in Section 4.2.6 a committee has been formed in Ontario to study institutional barriers as a preliminary step to their removal. This will need to be done in all provinces where NGV will be available in the future. The adoption of the current CGA standards by all provincial governments and a repeal of inappropriate legislation by municipalities in preparation for the adoption of NGV would be very useful.

### 5.8 Lack of Technological Developments

Research and development into ways of improving the NGV system is continuing and will eventually bring about increased reliability, a larger potential market, dependable diesel conversions, greater convenience and possibly lower costs.

# APPENDIX A

## STANDARDS AND FINANCIAL ANALYSIS OF VEHICLE CONVERSIONS

## Appendix A

## STANDARDS AND FINANCIAL ANALYSIS OF VEHICLE CONVERSIONS

If the price of NGV from a local filling station is given on a litre-equivalent basis, the task of determining the payback of an NGV conversion is quite simple. The litre-equivalent price of NGV is the price charged for that amount of natural gas which provides motive power approximately equivalent to one litre of gasoline. NGV is actually sold (metered) by the kilogram, but the litre-equivalent price is sometimes given by the operator. It has been suggested that the price of NGV be advertised in cents per one-half kilogram so that its price is roughly comparable to that of a litre of propane.

In the example of a Calgary taxi conversion given in Section 1.1., the payback was less than one year. This is determined as follows:

Assumptions:

Total annual kilometres driven - 80,000 km/yr
Taxi fuel efficiency - 20 L/100 km

Gasoline - 41.5¢/L

NGV - 26.5¢/L

Fuel price differential in Alberta - 15¢/L
(Price gasoline - price NGV litre-equivalent)

Fuel consumption - 16,000 L/yr

Calculations:[1]

Annual fuel cost saving - 16,000 L x 15¢/L = $2,400

Conversion cost $2,500 - $500 (federal grant) = $2,000

Payback period $\frac{\$2,000}{\$2,400}$ = 0.833 years

---

[1]Neither the time value of money nor the increased efficiency of natural gas is considered in these calculations.

If the same taxi is operated in Montreal where the fuel price differential is even higher at 20 cents per litre and a conversion grant from Gaz Metropolitain of $450 is available the payback is even faster. This is shown as follows:

Assumption:

20¢/L fuel price differential

Calculations:

Annual fuel cost saving 16,000 L x 20¢/L = $3,200

Conversion cost $2,500 - $500 (federal grant) - $450 (Gaz Metropolitain grant) = $1,550

Payback period $\frac{\$1,550}{\$3,200}$ = 0.480 years

The economic attractiveness of converting a vehicle to NGV is very sensitive to the annual mileage of the vehicle and the fuel price differentials. A light half-ton truck used on a farm in Alberta, for example, might not be as good a candidate for conversion as the taxi is. For example:

Assumptions:

Total annual kilometres driven - 30,000 km/yr
Truck fuel efficiency - 16 L/100 km

Gasoline - 41.5¢/L
- 6.3¢/L Federal fuel rebates
- 7.0¢/L Alberta fuel rebates
28.2¢/L

NGV - 26.5/L

Fuel price differential - 1.7¢/L

Fuel consumption - 4,800 L

Calculations:

Annual fuel cost saving - 4,800 L x 1.7¢/L = $81.60

Conversion cost $2,500 - $500 = $2,000

Payback period $\frac{\$2,000}{\$81.60}$ = 24.5 years

The attractiveness of converting a farm truck would also be strongly influenced by the remoteness of the location. A farmer around Vegreville, Alberta might wish to convert a vehicle because an NGV filling station will be established there in the near future. However, a farmer around Coronation or Provost, both fairly remote locations in East-Central Alberta, would not find a filling station located within a hundred miles (and likely won't for the foreseeable future) and therefore probably would be very reluctant to convert. At $7,000, prototype home compressors are expensive even for farming operations.

If the same farm truck were converted to NGV in Quebec, where fuel prices are higher but the price differential is also higher, the conversion would be financially attractive, with a payback of 2 years. Preliminary investigation has revealed that larger agri-business farms can utilize NGV economically if all fuel requirements are met with natural gas. (See Canadian Resourcecon (1983) Limited, The Potential for Use of Natural Gas as a Farm Vehicle and Equipment Fuel in Alberta and Saskatchewan, Final Report, October 1984.)

It should be noted that compression and other refilling station overhead costs are a significant portion of the NGV cost. The natural gas cost component is quite small as shown by the following example.

In Calgary the base residential energy charge for natural gas is $2.57 per gigajoule (GJ). The net heat content of natural gas is 0.0479 gigajoules per kilogram (kg). The cost per kilogram is therefore (0.0479 GJ/kg x $2.57/GJ) $0.123 per kilogram. One litre of gasoline is equal to about 0.67 kilograms of natural gas. Therefore, the litre-equivalent price of natural gas in Calgary is ($0.123/kg x 0.67) $0.082. The capital amortization charge of the compression facilities would amount to another 10 cents per litre equivalent.

For illustration purposes the following "Economic Analysis Format" provides a methodology for determining the Net Present Value of a conversion investment for a company which would own its own fleet and compression system. This "Format" is reprinted from American Gas Association, Compressed Natural Gas (CNG): A Vehicle Fuel For Utility Company Fleets - the Pros and Cons (Arlington: American Gas Association, February 1982), Appendix B. If a payback or rate-of-return analysis is preferred, examples of these are contained in Annex J of Natural Gas, Canada's Transportation Fuel.

EXHIBIT A.1

DRAFT
NOVEMBER 29, 1983

CANADIAN GENERAL
STANDARDS BOARD

Standard for

# NATURAL GAS FOR VEHICLES (NGV)

## 1. SCOPE

1.1 This standard applies to natural gas consisting predominantly of methane.

1.2 For further information on uses, see par. 6.1.

## 2. APPLICABLE PUBLICATIONS

2.1 The following publications are applicable to this standard:

2.1.1 American Society for Testing and Materials (ASTM).

Annual Standards for Petroleum Products and Lubricants.

E-29 - Recommended practice for Indicating which Places of figures are to be Considered Significant in Specified Limiting Values.

2.2 Reference to the above publications is to the latest issues, unless otherwise specified by the authority applying this standard.

## 3. GENERAL REQUIREMENTS

3.1 Natural gas shall be odourized to ensure that it is readily detectable in air at all concentrations of one-fifth of the lower explosive limit (1.0% vol.) and above.

3.2 The product shall be free from harmful quantities of deleterious substances.

EXHIBIT A.1
(Continued)

4. DETAIL REQUIREMENTS

4.1

| | Min | Max | ASTM | |
|---|---|---|---|---|
| Methane, % vol | 92 | - | 1945 | These limits |
| Sulphur, mg/kg | - | 20 | 1072 or 3031 | are to be |
| Hydrogen sulphide, mg/kg | - | 2 | 2725 or 4084 | redefined |
| Water, mg/kg | - | 80 | 1142 | pending in- |
| Net heat content, MJ/kg | 47 | - | 3588 | put from CGA. |

5. INSPECTION

5.1 Sampling - A sample of the size required by the laboratory conducting the test shall be provided and shall be obtained in accordance with ASTM D 1145.

6. NOTES

6.1 Intended Uses - This gas is intended for use in internal combustion engines.

6.2 Energy Equivalence - The natural gas to gasoline energy equivalence for automotive purposes is defined by the following equation:

$$1.00 \text{ L gasoline} = \frac{H_g \times D_g}{H_{NG}} = 0.67 \pm 0.02 \text{ kg of NG}$$

where $H_g$ = gravimetric net heat content of gasoline (43.8 $\pm$ 0.5 MJ/kg)

$D_g$ = density of gasoline at 15°C (0.73 $\pm$ 0.04 kg/L)

$H_{NG}$ = gravimetric net heat content of natural gas (47.9 $\pm$ 1.0 MJ/kg)

SOURCE: Canadian General Standards Board, Proposed Draft, 1983.

EXHIBIT A.2

VEHICLE EQUIPMENT STANDARDS

Standard for

NATURAL GAS FOR VEHICLES
(NGV)

The following national standards apply to NGV conversions:

- CGA12.3, Preliminary Standard for Compressed Natural Gas Fuel System Components for Use on Highway Vehicles, applies to the construction and performance of NG fuel system components providing motive power for highway vehicles. Preliminary Standard published 1981.

- CAN1-B149.1-M80, Installation Code for Natural Gas Burning Appliance and Equipment, applies to the storage, handling, transportation, and transfer of NG, and to the installation of equipment and containers. Latest update 1980.

- Amendment No. 1 to CAN1-B149.1-M80, Installation of Compressed Natural Gas Fuel Systems and Containers on Highway Vehicles, and Requirements for Refuelling Stations, sets out the requirements for the installation of NGV fuel systems and containers on highway vehicles and the requirements for NGV refuelling stations. Standard published October 1982.

For further information on standards governing conversions and components, contact the Canadian Gas Association, 55 Scarsdale Road, Don Mills, Ontario M3B 2R3. Telex No. 06-966824.

SOURCE: Energy, Mines and Resources Canada, "Natural Gas, Canada's Transportation Fuel," Report TE-84-03, report prepared by John S. Heenan (Ottawa: Energy, Mines and Resources Canada, 1984).

# EXHIBIT A.3

ECONOMIC ANALYSIS FORMAT

February 18, 1981

ECONOMIC ANALYSIS FORMAT

This format was submitted by Mr. E. H. Burrows of Union Gas of Canada, and was revised by Mr. W. B. Withers of the A.G.A. Engineering & Operations Analysis Committee to reflect U.S. tax investment credit information.

A. Wherever the user might prefer to make a direct estimate of the value instead of building up his estimates at a basic level and then calculating the desired value, I have indicated this possibility by two asterisks joined by a vertical line. The vertical line, of course, represents the number of items that might possibly be skipped if the bottom value is directly estimated.

B. I tried to substitute investment tax credit calculations in place of the Canadian Tax Shield. It is my understanding that the Investment Tax Credit can be taken in a lump sum at the origin of a given project requiring capital expenditure of the correct type; thus, I have treated it as a deduction from the capital required. Since all required capital occurs at the initiation of this project, except for the hypothetical replacement of the gas compressor, it is not necessary to deflate any of the ITC by worth mechanics.

C. I did not understand the formula underlying the calculation of the CCA benefits, and, therefore, I substituted only the nominal value of the investment tax credit as before described.

D. Some rearrangement of the form has been done regarding shipping cost, tax benefits from depreciation, etc., but this did not affect the calculation as Mr. Burrows had designed it.

SOURCE: American Gas Association, Compressed Natural Gas (CNG): A Vehicle Fuel for Utility Company Fleets - The Pros and Cons (Arlington: American Gas Association, February 1982).

In addition I would like to make the following comments on simplifying the use of this form. The notes appear in the left hand margin of the pages where appropriate and might be included as directions to users if the form were given wide circulation.

Note 1: In my opinion, a proper cost for MCF of natural gas cannot be assigned to this project until a decision is made as to whether a sale is thereby forfeited. If this be the case then the appropriate cost is the cost of the interruptible (or other sale) foregone, since this is the opportunity cost of this gas consumption. If no sale is being curtailed for this consumption then the appropriate cost is the city gate cost of the gas plus some allowance for loss during distribution.

Note 2: The cost of electricity to run the compressor can be developed as per Mr. Burrows form. However, a short cut method might be employed as follows. An empirical expression for work required to compress gas exists as follows:

$$\text{BHP/MMCFD} = 223\ (R^{.2157} - 1) + 3$$

Assuming an average main pressure of 30 PSIG an average cylinder pressure of 2400 PsIG and then average mechanical efficiency of the compressor of 90%, the amount of energy thus required would be 6.3 kilowatt hours per MCF. If an arbitrary value of 5 or 6 cents per KWH is assigned to the cost of electric power the approximate number of 6.3 KWH per MCF might be a more convenient tool of estimation than attempting to estimate the hours of operation of the compressor per day.

Note 3: The tax rate, which has been carried within the work sheet as X% should be the incremental tax rate rather than overall average tax rate.

Note 4: The corporate cost of capital, designated as Y% throughout, should be the cost of incremental capital rather than be embedded cost.

Note 5: The work sheet calls for the present value factors to be looked up in tables: I believe these could be more easily calculated from scratch by use of the following formulas:

$$\text{Present Worth of an Annuity of \$1} = \frac{1-e^{-rt}}{r}$$

$$\text{Present Worth of a Lump Sum of \$1} = e^{-rt}$$

Where: r = Corporate Cost of Capital (after allowance for tax deduction for debt interest), &
t = Life of annuity, or time of payment of lump sum.

Sincerely,

William D. Withers

William D. Withers
WDW/lap
Enclosure

cc: James F. Wright

GENERAL FORM: TO CALCULATE THE NET PRESENT VALUE OF THE CONVERSIONS OF GASOLINE FUELED VEHICLES TO DUAL FUEL VEHICLES (WHICH OPERATE ON COMPRESSED NATURAL GAS OR GASOLINE).

SECTION 1 ANNUAL FUEL SAVINGS

SECTION 2 PRESENT CAPITAL EXPENDITURES

SECTION 3 FUTURE CAPITAL EXPENDITURES

SECTION 4 FUTURE EXPENSES

SECTION 5 FINANCIAL CALCULATIONS

SECTION 6 ASSUMPTIONS MADE

-1-

NET PRESENT VALUE CALCULATION

(For conversion from gasoline to dual fuel vehicles)

SECTION 1: ANNUAL SAVINGS

- PRESENT COST OF FUELING VEHICLES WITH GASOLINE

  Number of vehicles to be converted _____(1)

  Average gasoline consumption per vehicle per day _____(2)

  Number of working days per year _____(3)

- Number of gallons of gasoline presently consumed per year ((1)x(2)x(3))_____(4)

  Cost per gallon of gasoline _____(5)

  Gasoline cost for 1 year of operation ((4)x(5)) _____(6)

COST OF FUELING VEHICLES AFTER CONVERSION TO DUAL FUEL

Expected amount of dual fuel vehicle mileage on natural gas _____%(7)

COST OF NATURAL GAS

Number of gallons of gasoline consumed per year (from (4)) _____(8)

Number of gallons of gasoline to be replaced by natural gas ((7)x(8)/100) _____(9)

Number of cubic feet of natural gas equivalent to one gallon of gasoline _____(10) (100 in U.S.)

Number of cubic feet of natural gas consumed per year to drive vehicles ((9)x(10))_____(11)

(Note 1) Cost per Mcf of natural gas _____(12)

Natural gas cost for 1 year of operation ((11)x(12)/1000) _____(13)

COST OF GASOLINE TO SUPPLEMENT NATURAL GAS

Expected amount of dual fuel mileage on gasoline (100% - (7))_____%(14)

Gasoline cost for 1 year of gasoline only operation

(from (6)) _____(15)

Cost of gasoline to supplement natural gas ((14)x(15)/100) _____(16)

COST OF ELECTRICITY TO RUN COMPRESSOR

Power of motor driving compressor _____hp (17)

(1 H.P. = 0.746kw)

Number of hours of compressor operation required per day to refuel

vehicles _____(18)

Amount of work per day required to compress the natural gas

((17)x(18)) _____kw-hr (19)

Number of working days per year (from (3)) _____(20)

(Note 2) Amount of work required per year to compress the natural gas

((19)x(20)) _____kw-hr (21)

Cost per unit of electricity $_____/kw hr. (22)

Cost of electricity to run compressor ((21)x(22)) _____(23)

Cost of electrical demand

Expected charge per month _____(24)

Electrical demand cost/year ((24)x12 $\frac{\text{months}}{\text{year}}$) _____(25)

* COST OF COMPRESSOR MAINTENANCE

Estimated maintenance cost per cubic foot of natural gas

compressed _____(26)

Number of cubic feet of natural gas compressed per year

(from (11)) _____(27)

Compressor maintenance cost for 1 year of operation (20x(27))_____(28)

TOTAL FUELING COSTS PER YEAR AFTER CONVERSION TO DUAL FUEL

((13)+(16)+(23)+(25)+(28))_____(29)

YEARLY FUELING COST SAVINGS ((6) - (29))_____(30)

## SECTION 2: PRESENT CAPITAL EXPENDITURES

A. COMPRESSOR COST

Price _____

Add: Exchange (if applicable) _____

Sales Tax _____

Installation Cost (____Manhours @ $____per Manhours) _____

Total Cost _____(31)

B. VEHICLE CONVERSION KIT COST

Price per kit _____

Add: Exchange (if applicable) _____

Sales Tax _____

Installation Cost (____Manhours @ $____per Manhours)

Total Cost Per Vehicle _____

Total Cost for all_____Vehicles _____(32)

C. FILL HOSE COST (Flexibel hose with quick connect fitting to attach high pressure piping to trucks)

Price per hose _____

-4

Add: Exchange (if applicable) _____

Sales Tax _____

Installation Cost (____Manhours/1 hose @ $____per Manhour) _____

Total Cost Per Hose _____

Total Cost for_____Hoses _____(33)

D. DUAL LOAD REGULATOR (Controls maximum pressure of truck fuel tanks based on ambient temperature)

Price _____

Add: Exchange (if applicable) _____

Sales Tax _____

Total Cost for____Vehicles _____(34)

* E. SHIPPING COSTS

| Items to be shipped | Cost |
|---|---|
| Compressor | _____(35) |
| Conversion kit (including fuel tanks) | _____(36) |
| Fill hoses | _____(37) |
| Dome load regulator | _____(38) |
| Other _____ | _____(39) |
| _____ | _____(40) |

* Estimated Cost _____(41)

F. COMPRESSOR BUILDING COST (Building to house compressor, properly vented to prevent leaking gas buildup)

Size of building required ____W____W____

Foundation type (ie. 8" concrete slab)

_____

_____

Estimated Cost _____(43)

* G. NATURAL GAS LINE FROM NEAREST GAS PIPELINE TO COMPRESSOR LOCATION

Length of line _____ft. (43)

Line size _____inches diameter

Cost per foot for installation of a line of the given diameter

_____(44)

* Cost Of The Line ((43)x(44)) _____(45)

* H. HIGH PRESSURE GAS LINE:FROM COMPRESSOR TO LOCATIONS WHERE TRUCKS ARE PARKED FOR REFUELING

Total Length of piping _____ft. (46)

Line size _____inches diameter

Cost per foot to dig trench and lay pipe _____(47)

Cost to dig trench and lay pipe ((46)x(47)) _____(48)

Welding cost (weld & X-Ray) _____(49)

Dig up asphalt and re-asphalt _____(50)

* Estimated Cost ((48)+(49)+(50)) _____(51)

I. MISCELLANEOUS COSTS

| | |
|---|---|
| Meter to determine gas usage | _____ |
| Regulators | _____ |
| Other _____ ___ | _____ |
| _____ | _____ |
| _____ | _____ |

Total _____(52)

SUB TOTAL CAPITAL COSTS _____(53)

((31)+(32)+(33)+(34)+(41)+(42)+(43)+(51)+(52))

CONTINGENCY _____%(54) of (53) _____(55)

TOTAL CAPITAL COSTS((53 + 55)) _____(56)

## SECTION 3: FUTURE CAPITAL EXPENDITURES

The compressor will probably have a much shorter useful life than the other capital investments such as piping, building and conversion kits. Thus it might be advantageous to purchase a new compressor when the first one wears out to extend the life of the project.

The following section calculates the present value of the costs to replace the compressor at some point during the life of the project.

CASH EXPENDITURE

Cost of compressor and installation ((31) + (35)) _____(57)

Add contingency (from(54)) _____% of (57) _____(58)

Total replacement compressor cost ((57) + (58)) _____(59)

Salvage value of old compressor (net of cost of removal and may be negative) _____(60)

Cash expenditure made in year of replacement ((59) - (60)) _____(61)

INVESTMENT TAX CREDIT

(Note 3) Tax rate X % = ___% _____(decimal)(62)

(Note 4) Corporate cost of capital Y % = ___% (after allowance for tax deduction for debt interest) _____(decimal)(63)

Value of investment tax credit in year of second compressor purchase ((59) x .10) _____(64)

PRESENT VALUE OF COSTS

Net cost of compressor replacement in the year of replacement _____(65)
((61) - (64))

Year in which replacement is made (ie., 8th., 10th) _____

Present value of $1 paid in year of replacement at Y% discount rate
(from (62)) (Look up in tables) _____(66)

Net present value of cost of replacing the compressor((65)x(66))_____(67)

NOTE:

Section 4 and 5 should be completed twice, once assuming no replacement compressor purchase (project life will probably be the life of the first compressor) and once assuming a replacement compressor is purchased (project life may be determined by the useful life of the second compressor, conversion kit or piping).

## SECTION 4: FUTURE EXPENSES

EXPENSES TO TRANSFER CONVERSION KITS TO NEW VEHICLES WHEN PRESENT VEHICLES ARE TRADED IN.

Number of manhours required to remove one conversion kit from an old vehicle and reinstall it in a new vehicle _____(68)

Number of manhours required to have the two gas cylinders pressure tested _____(69)

Total manhours required for one transfer ((68)+(69)) _____(70)

Labor cost per manhour _____(71)

Labor cost per transfer ((70)x(71)) _____(72)

Charge for pressure testing of the two gas cylinders _____(73)

Total transfer cost per vehicle ((72)+(73)) _____(74)

Number of vehicles on dual fuel (from (1)) _____

Total cost of transfer ((74)x(1)) _____(75)

Years in which transfers will be made (ie., 5th, 10th) _____(76)

## SECTION 5: FINANCIAL CALCULATIONS

A. DETERMINE SAVINGS IN EACH YEAR OF THE INVESTMENT AND FIND THE PRESENT VALUE OF THESE SAVINGS.

Yearly fuel cost savings (from (30)) _____(77)

Local taxes per year allocated to this project _____(78)

(ie. 2.0%) of initial capital cost

Yearly savings before income tax ((77)-(78)) _____(79)

(Note 3) Tax rate X % = ___% _____(decimal)(80)

Taxes (Note: Investment Tax Credit is accounted for subsequently) ((79)x(82)) _____(81)

Yearly savings after income tax ((79)-(81)) _____(82)

Life of investment _____(83)

Tax cost of capital = Y% = for (63) _____(84)

Present value of an annuity of $1 for X years (from (83)) at Y% discount rate (from (84)). Look up in tables _____(85)

Present value of after tax savings ((82)x(85)) _____(86)

B. PRESENT VALUE OF THE INVESTMENT TAX CREDIT

3 years _ asset life 5 years

Total conversion kit cost (32) _____(87)

Shipping Cost (36) _____(88)

Proportion of miscellaneous costs (from (52)) _____(89)

Contingency costs @ (% from (54)((87)+(88)) _____(90)

Investment tax credit (3.33% of (87)+(88)+(89)+(90))_____(91)

NOTE: Election must be made for fueling facilities, compressors, pipelines, etc., as to whether amortization period is less than or greater than 5 years.

5 years ≤ asset life < 7 years

Total compressor cost from (31) _____(92)

Fill Hose Installations from (33) _____(93)

Pipeline to fill site from (45) _____(94)

Shipping Cost ((35)+(37)+(38)+(39)+(40)) _____(95)

Proportion of miscellaneous costs _____(96)

Contingency costs @ _____% (from (54)) _____(97)

Investment Tax Credit (6.67% of (92)+(93)+(94)+(95)+(96)+(97))

_____(98)

NOTE: Election must be made for fueling facilities, compressors, pipelines, etc., as to whether amortization period is less than or greater than 7 years.

Asset life > 7 years

Total compressor cost from (31) _____(99)

Fill Hose Installations from (33) _____(100)

Pipeline to fill site from (45) _____(101)

Shipping Cost ((35)+(37)+(38)+(39)+(40)) _____(102)

Proportion of miscellaneous costs _____(103)

Contingency costs @ ____% (from (54)) _____(104)

Investment Tax Credit (10% of (99)+(100)+(101)+(102)+(103)+(104))

_____(105)

Total present value of Investment Tax Credit((91)+(98)+(105))

_____(106)

C. DETERMINE THE PRESENT VALUE OF EXPENSES TO TRANSFER THE CONVERSION KITS TO NEW VEHICLES.

Expenses (from (75)) _____(107)

Tax rate (from (80)) _____(108)

Value of tax deduction produced by expensing of conversion (0 x %)

kit transfer ((107) x (108)) _____(109)

Net cash outflow ((107) - (109)) _____(110)

Years in which transfers will be made (from (76)) _____(111)

Corporate cost of capital (from (63)) _____(112)

Present value of $1 paid in the years of transfer with discount rate equal to the corporate cost of capital

Find in tables

Transfer 1 _____(113)

Transfer 2 _____(114)

Transfer 3 _____(115)

Transfer 4 _____(116)

Total present value of transfer expenses

((113) + (114) + (115) + (116)) _____(117)

D. PRESENT VALUE OF DEPRECIATION RELATED TAX BENEFIT.

Life of Vehicle Conversion Kits (last transfer from (76) plus years equal to 1 transfer cycle) _____(118)

Original Cost of Conversion Kits

((87) + (88) + (89) + (90)) _____(119)

Straight-Line value of Annual Depreciation Expense of Conversion Kits ((119)/(118)) _____(120)

Tax Rate = _0_ % = ____ _____(decimal)(121)

Annual Value of Tax Benefit ((120)x(121)) _____(122)

Present Value of an Annuity of $1 for life of conversion kits at Corporate Cost of Capital, Y% (look up in tables) _____(123)

Present Value of Tax Benefit((122)x(123)) _____(124)

Year in which compressor replacement is made (if made) _____(125)

Original cost of compressor((57)+(58)) _____(126)

Straight-Line value of Annual Depreciation ((126)/(125)) _____(127)

Annual Value of Tax Benefit((121)x(127)) _____(128)

Present Value of Tax Benefit((123)x(128)) _____(129)

Original Cost of All Other Items ((56) - (119) - (126)) _____(130)

Straight-Line value of Depreciation Expense ((130)/(118)) _____(131)

Annual Value of Tax Benefit((121)x(131)) _____(132)

Present Value of Tax Benefit((123)x(132)) _____(133)

Total Present Value of Depreciation Related Tax Benefit((124) + (129) + (133)) _____(134)

E. CALCULATION OF THE NET PRESENT VALUE OF CONVERTING VEHICLES TO DUAL FUEL.

SAVINGS

Present value of fueling savings (from (86)) _____(135)

Present value of investment tax credit (106) _____(136)

Present value of Depreciation Tax Benefit (134) _____(137)

Total present value of savings ((135) + (136) + (137)) _____(138)

COSTS

Present value of capital expenditures (from (56)) _____(139)

Present value of capital expenditures on a second compressor if included in this NPV calculation (from (67)) _____(140)

Present value of future conversion kit transfer expenses (from (117)) _____(141)

Total present value of expenditures ((139) + (140) + (141)) _____(142)

Net present value ((138) - (142)) _____(143)

## SECTION 6: ASSUMPTIONS MADE

The assumptions implicit in this form are as follows:

1. A slow fill system was assumed which means that the dual fuel vehicles are refueled overnight in 12 - 14 hours. A "fast fill" system would be more expensive.
2. At the start all vehicles to be converted are new. Thus all initial capital expenditures are made in the same year. Also, as all dual fuel vehicles will be replaced in the same year, kit transfers are all made in the same years.
3. Maintenance costs for dual fuel vehicles are assumed to be equivalent to costs for gasoline driven vehicles.
4. The natural gas was assumed to be compressed by an electrically driven compressor.
5. Costs of transferring conversion kits to new vehicles are expensed. (ie., not capitalized)
6. No salvage benefits are assumed when calculating income tax benefits from depreciation expense.

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April 1985

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